



A 21st Century Observing System for California Weather and Climate: Current Plans and Future Possibilities

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Photo by Stephan Dietrich

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Outline

- Background
- Requirements/Drivers
- A Framework for Moving Forward
- A key scientific finding: Atmospheric Rivers
- A 4 Tiered approach to Modernizing CA's Observing System for weather and climate
- Conclusions

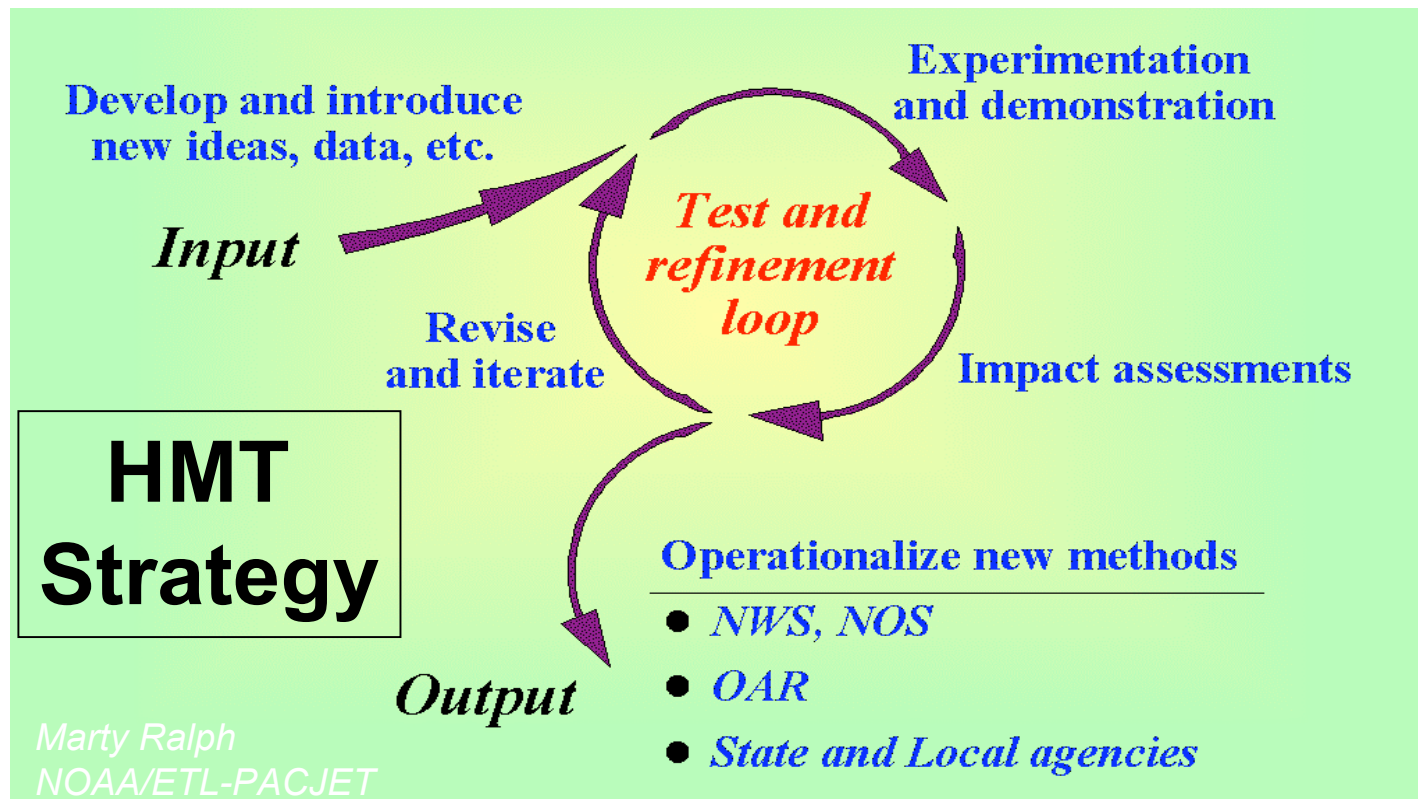
21st Century Observations Requirements/Drivers

Increasing vulnerability to extremes in precipitation, in terms of both weather and climate

- **Flood Risks**
 - Major basin hydrographs are more variable over last ~50 years
 - 6 of highest flows on American River occurred since Folsom dam was built
 - Similar results on Feather and San Joaquin Rivers
 - Earlier snowmelt combined with heavy spring storms raises flood risk
 - Need to redefine probable maximum precipitation and include the impacts of rain on snow
- **Water Resources**
 - Uncertainty in storm intensity and annual rainfall will require adaptable water management strategies
 - Should CA invest in more storage capacity or reoperate current reservoirs using improved weather forecast information? (Forecast-Based Operations)
- **Climate Change**
 - 25% reduction in snow pack by 2050
 - Earlier snowmelt pushes peak runoff into winter storm period and stresses water supply during dry season
 - Possible increase in extreme rainfall events

Background

A decade of relevant research, development and recent Hydrometeorological Testbed (HMT) activities have yielded many important lessons

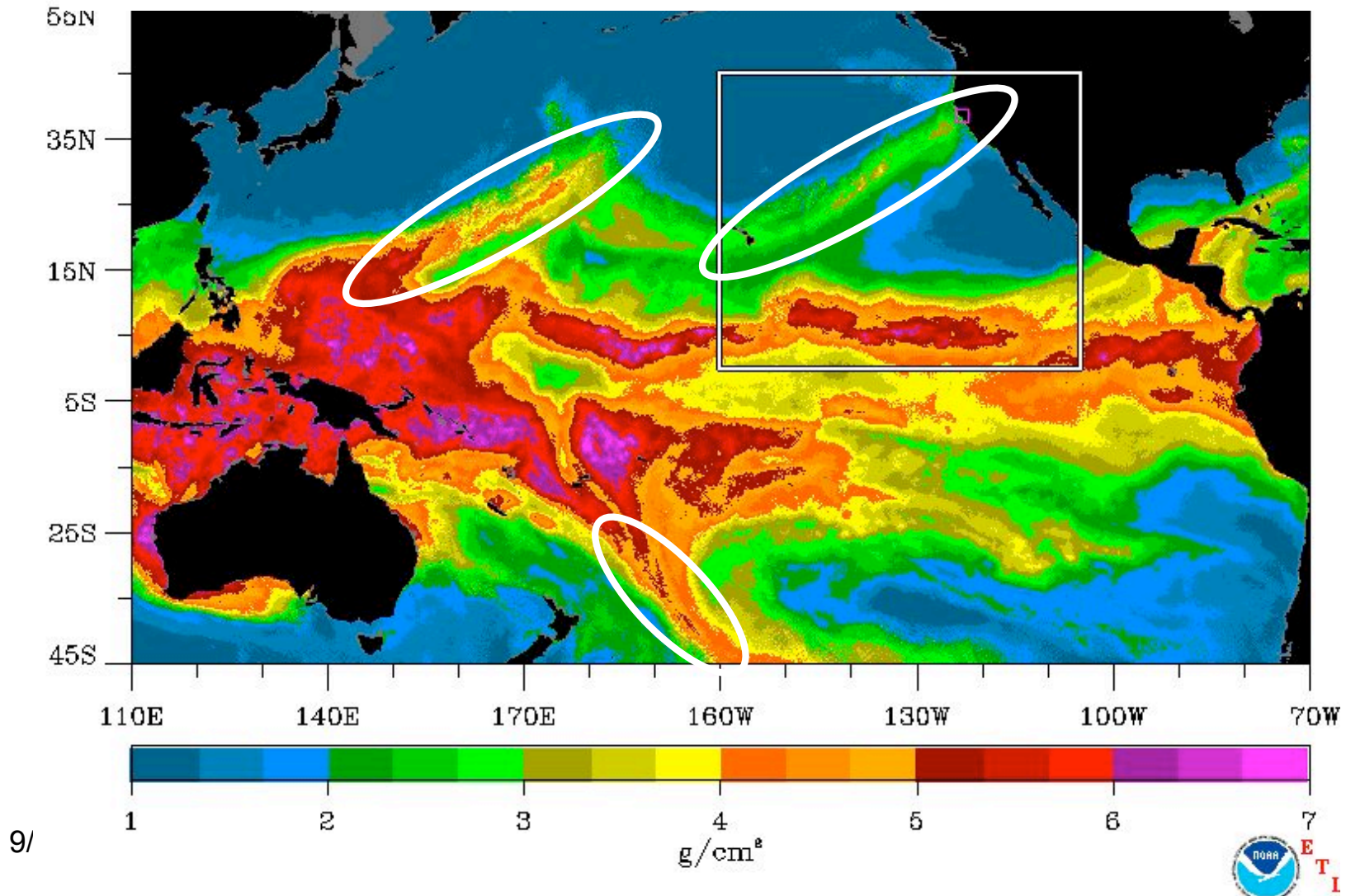


Key Formal References

- Zhu and Newell 1998, Mon. Wea. Rev.
- Pandey et al. 1999, J. Geophys. Res.
- Neiman et al. 2002, Mon. Wea. Rev.
- Ralph et al. 2003, J. Hydrometeor.
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- Ralph et al. 2004, Mon. Wea. Rev.
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- Dabberdt et al. 2005, Bull. Amer. Meteor. Soc.
- Matrosov et al. 2005, J. Hydrometeor.
- Ralph et al. 2005, Bull. Amer. Meteor. Soc.
- MacDonald 2005, Bull. Amer. Meteor. Soc.
- Ralph et al., 2006, Geophys. Res. Lett.
- Bao et al. 2006, Mon. Wea. Rev.
- Fahey et al. 2006, EOS
- Morss and Ralph 2007, Wea. Forecast.
- Neiman et al. 2007, J. Hydrometeor.
- Lundquist et al. 2007, J. Hydrometeor.

Atmospheric Rivers

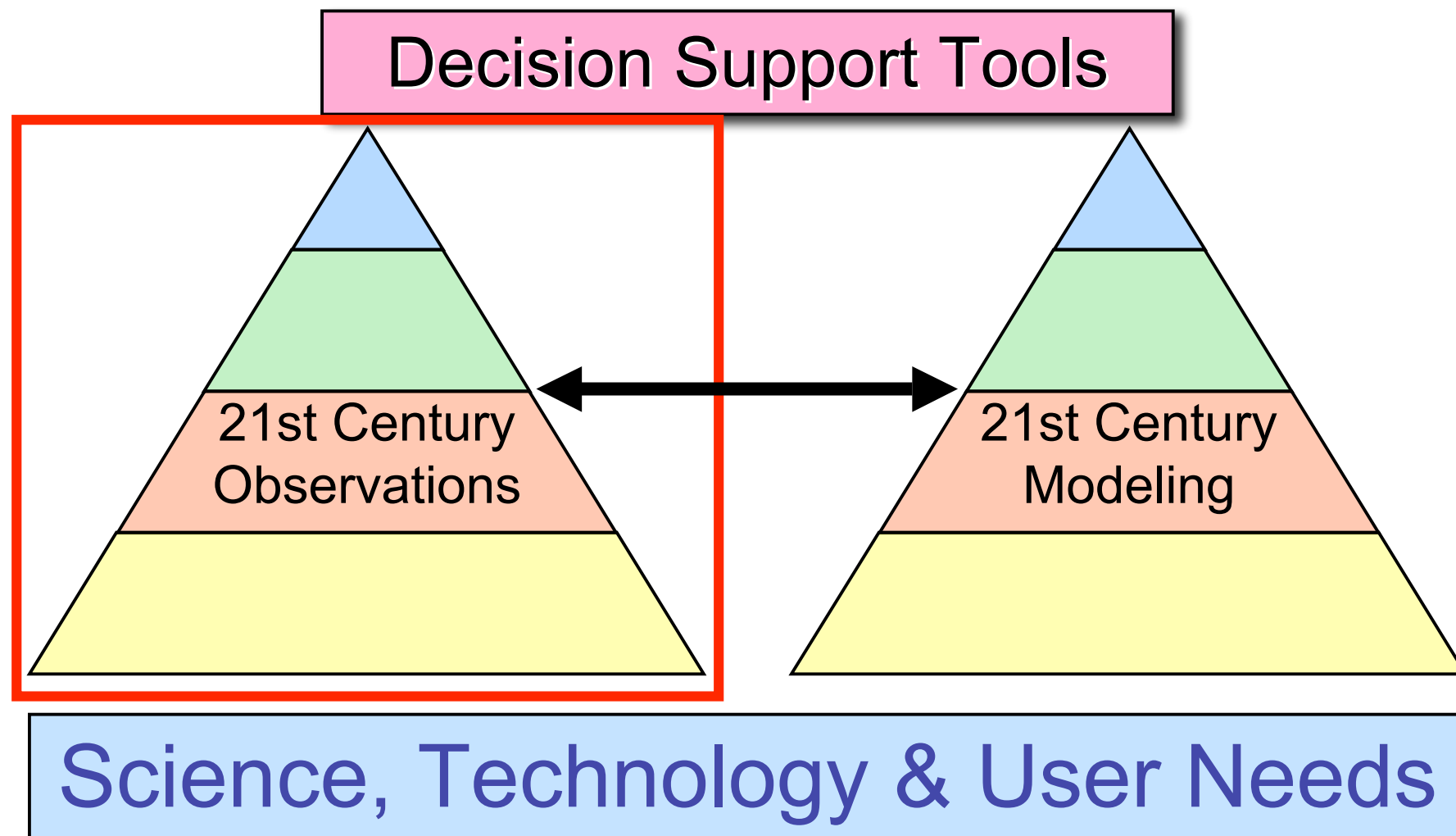
A key to understanding West Coast extreme precipitation events



Roles of Atmospheric Rivers (AR) in West Coast Hydrometeorology and Hydroclimatology

- ARs are responsible for many of the extreme precipitation events and have high “snow levels”
 - And thus also contribute significantly to floods
- ARs are responsible for a large fraction of the total annual rainfall in the area
- The precise timing, location, snow level and magnitude of extreme precipitation events are difficult to predict
- Changes in hydroclimatology are likely to be associated with (or partly due to) changes in AR amplitudes, frequency, etc. in future climate regimes

A Framework for Revolutionizing California's Weather and Climate Observing System for Water*



*Developed jointly by NOAA, CA DWR, Scripps and others

Next Generation Observations

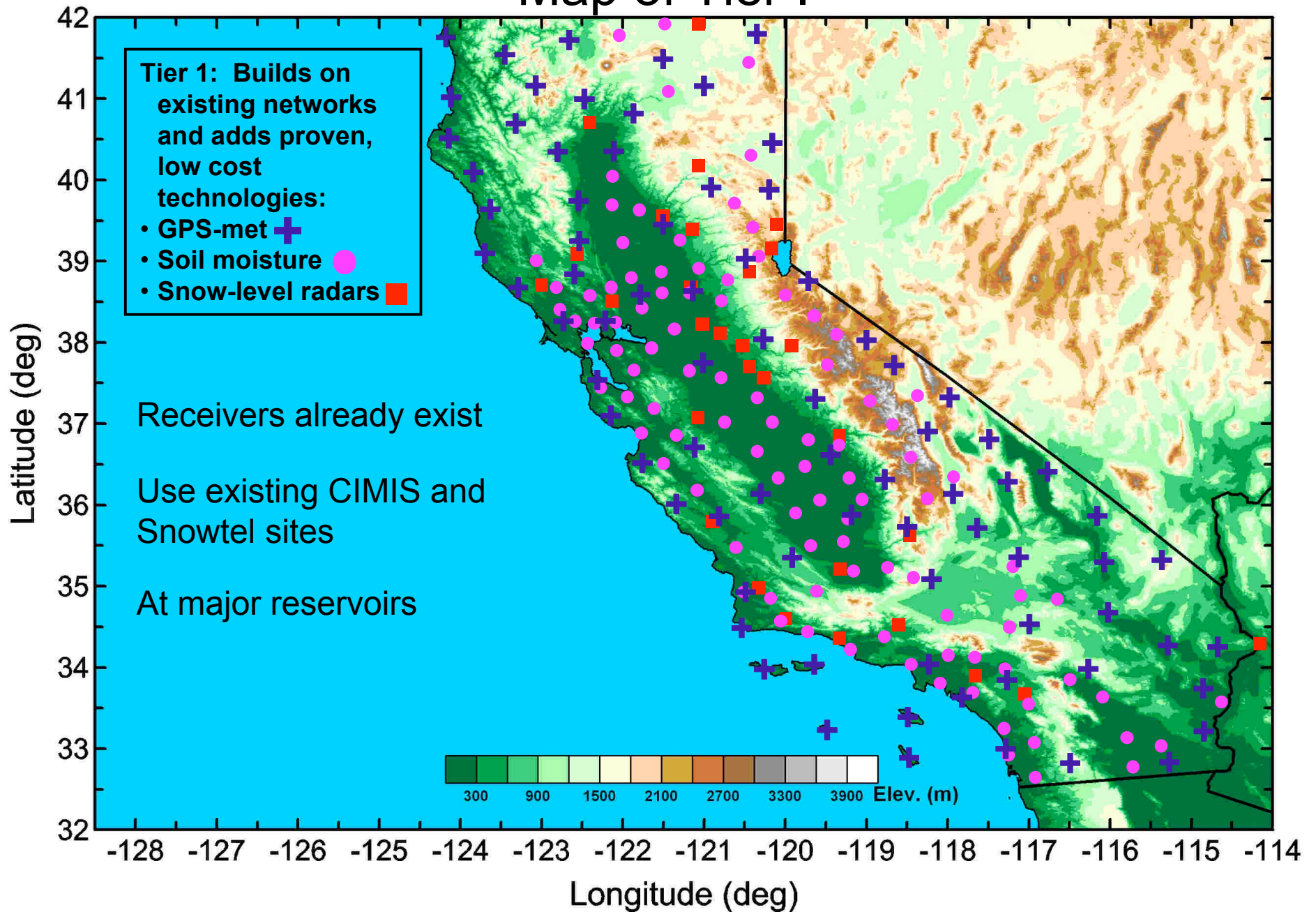
Four types of needs are addressed to improve flood control and policy:

- NWS Watch-warning system, e.g., flood watches/warnings (0-48 hours)
- Medium-to-extended range forecasting (2-14 days)
- Monitoring for climate change impacts on water (too much and too little)
- Scientific (weather and climate)

Four primary “Tiers” envisioned for next generation observations based on concept and technology maturity and feasibility:

- Tier-I: Well-defined needs, proven technology, low cost
- Tier-II: Well-defined needs, proven technology, moderate cost
- Tier-III: Needs assessment and technology prototype tests in HMT-West, high cost
- Tier-IV: Offshore aircraft reconnaissance, potentially very high cost/very high benefit

Map of Tier I



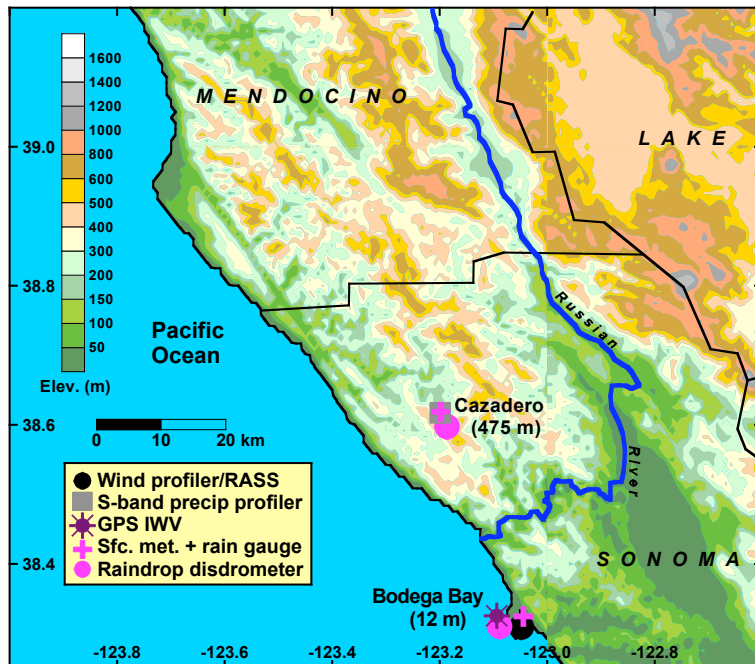
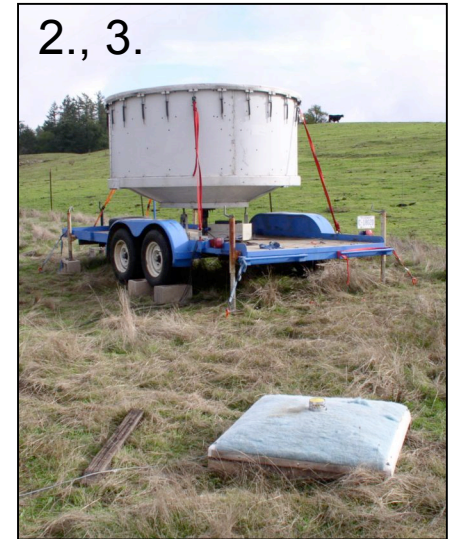
Tier 2: Atmospheric River Observatory

Atmospheric River (AR) Observatory: Russian River Prototype

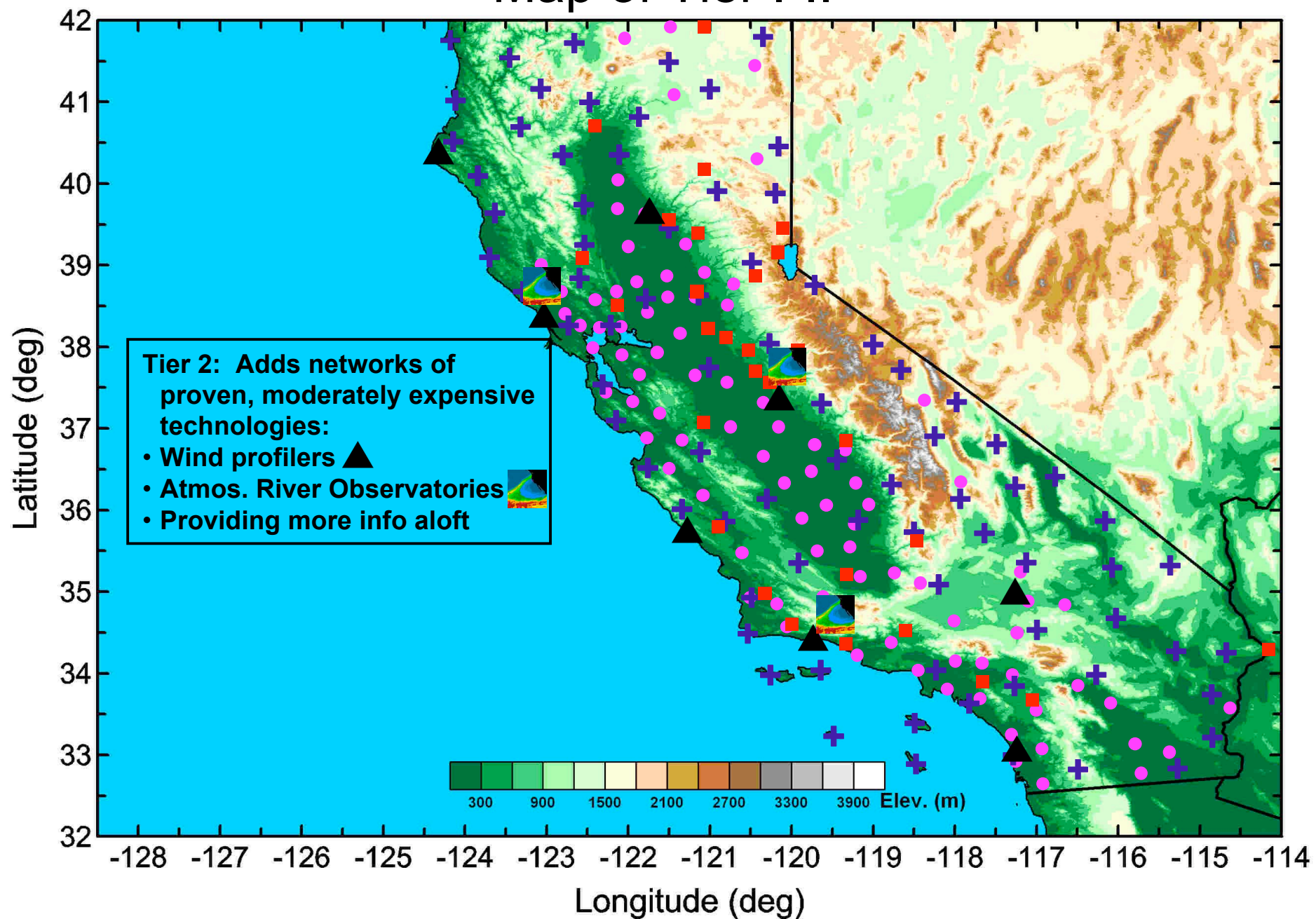
Objectives: Monitor key AR and precipitation characteristics.

Observing systems:

1. Wind profiler/RASS
2. S-band radar
3. Disdrometer
4. Surface met
5. GPS-IWV
6. Rain gauges

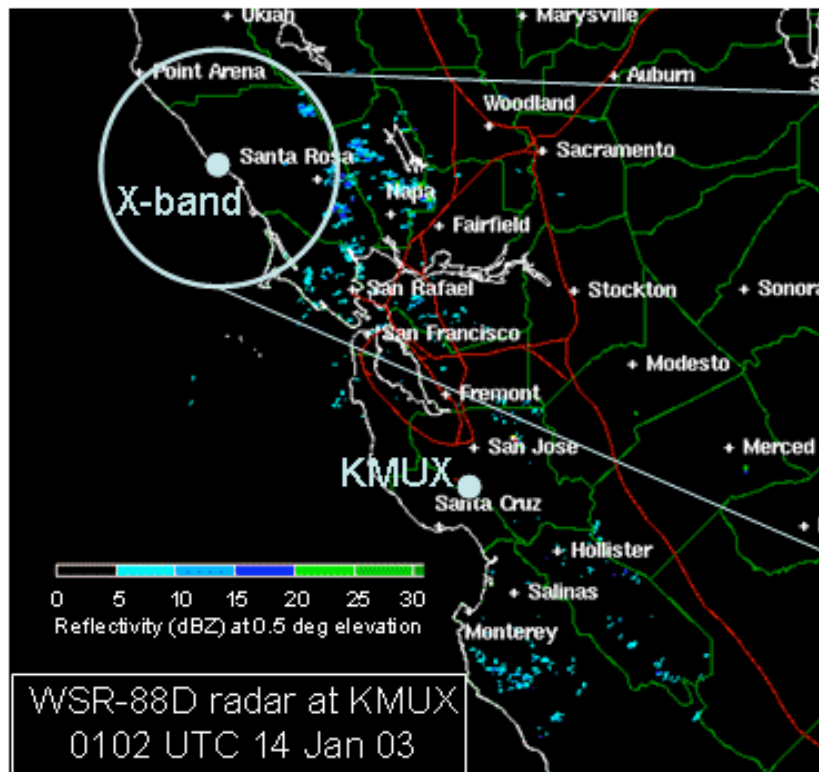


Map of Tier I-II

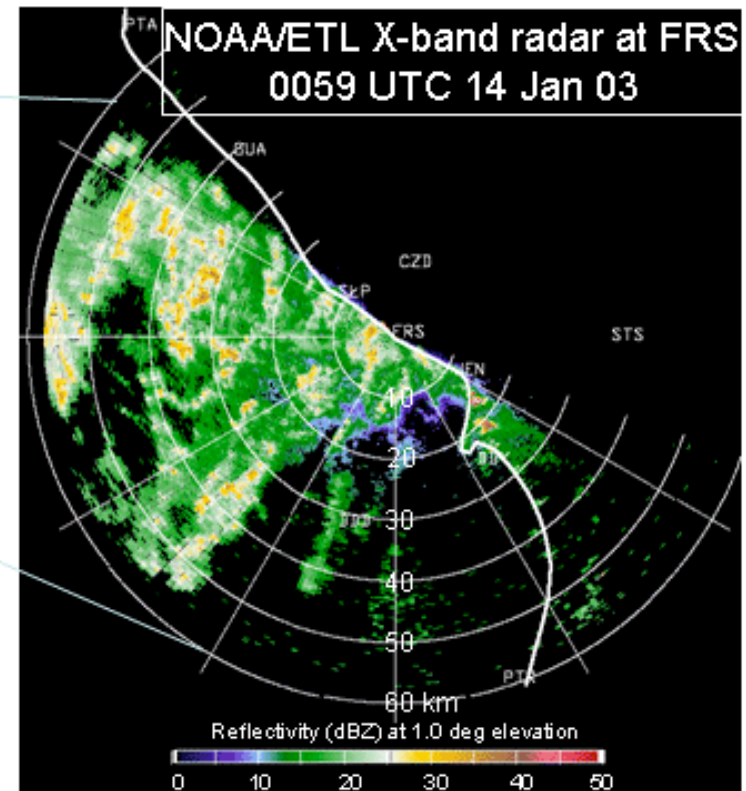


Tier 3: Gap Filling Scanning Radars

PACJET-2003: NOAA/ETL Gap-Filling X-band Radar



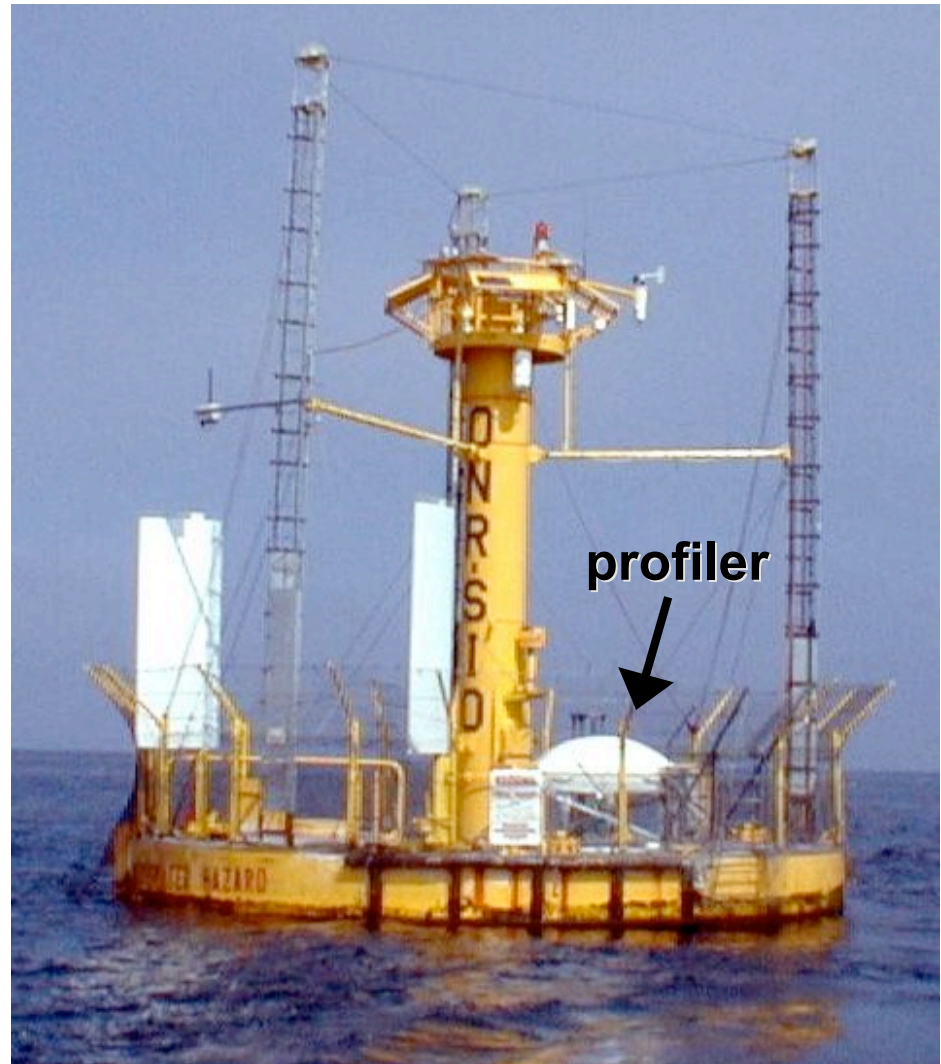
- Nearest NEXRAD radar sees no significant echoes approaching flood-prone watershed



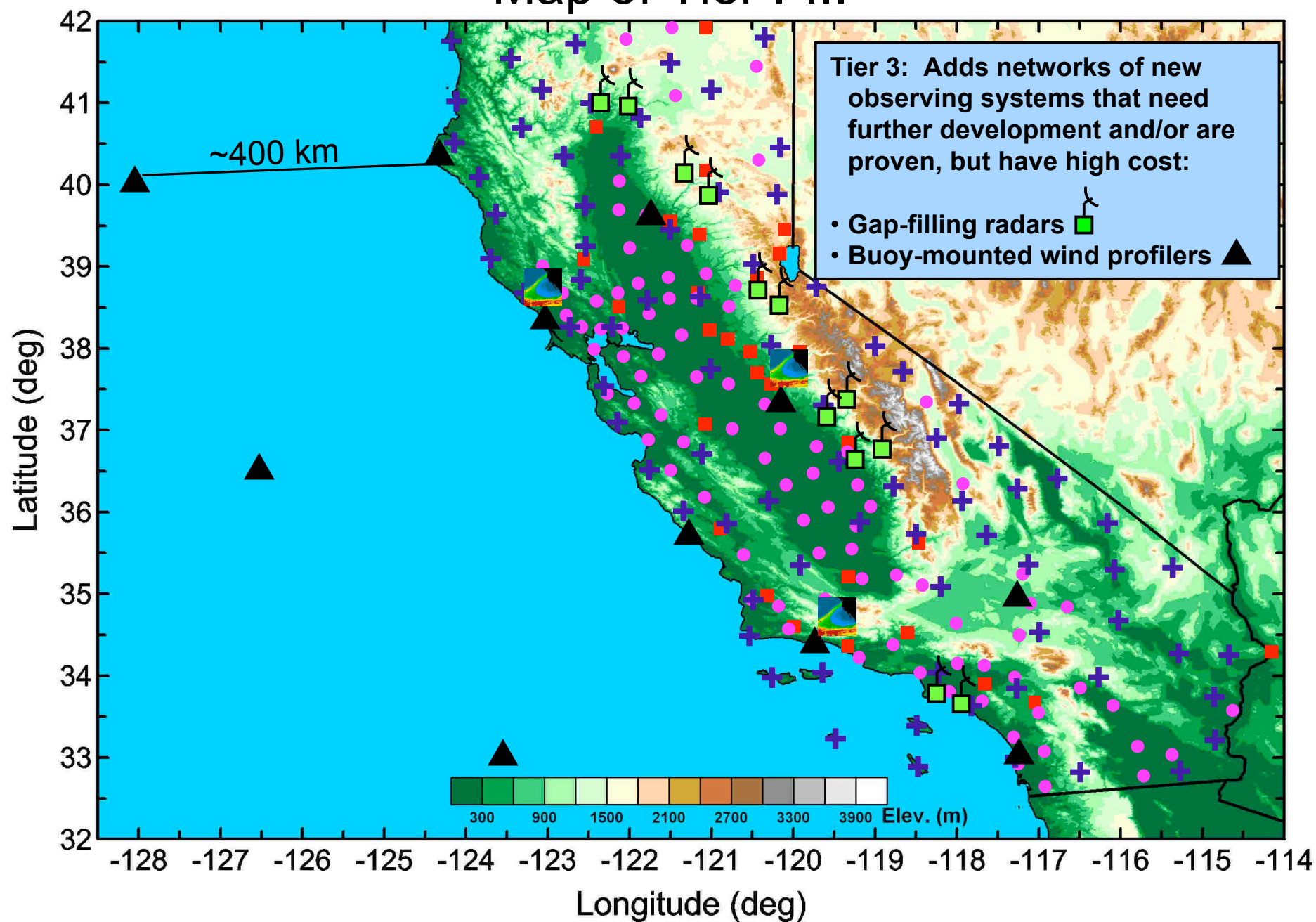
- NOAA/ETL's Coastal X-band radar fills NEXRAD gap

Tier 3: Buoy-mounted wind profilers

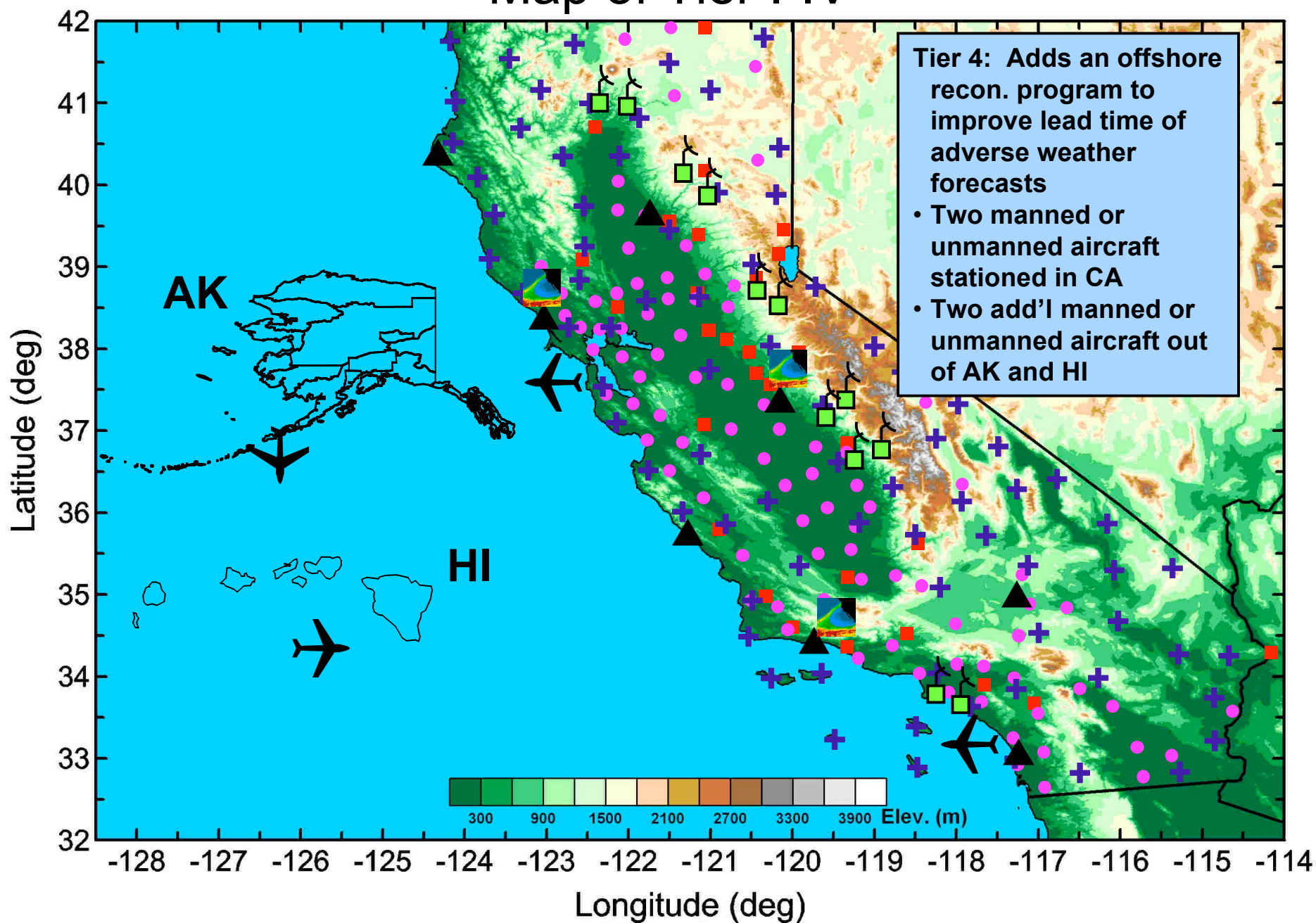
- Coastal and marine weather prediction suffers from a relative sparseness of coastal and offshore observations.
- USWRP Report No. 2 noted that “the most serious gap in the current observing system for 1-5 day forecasts is the absence of wind profiles, especially over the northeast Pacific Ocean.”
- A formal BMWP technology evaluation is part of the FY09-FY13 program plan in NOAA.



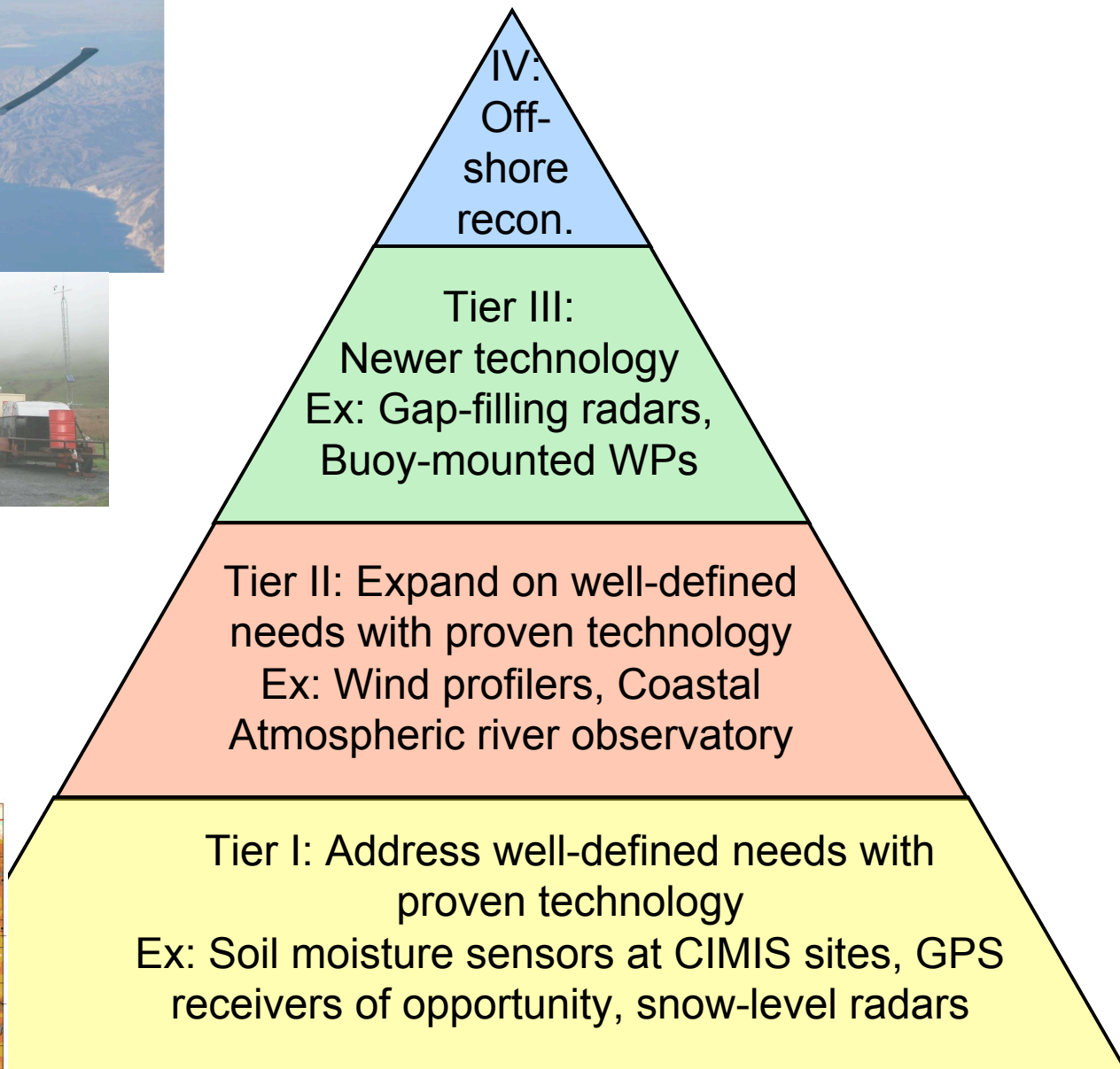
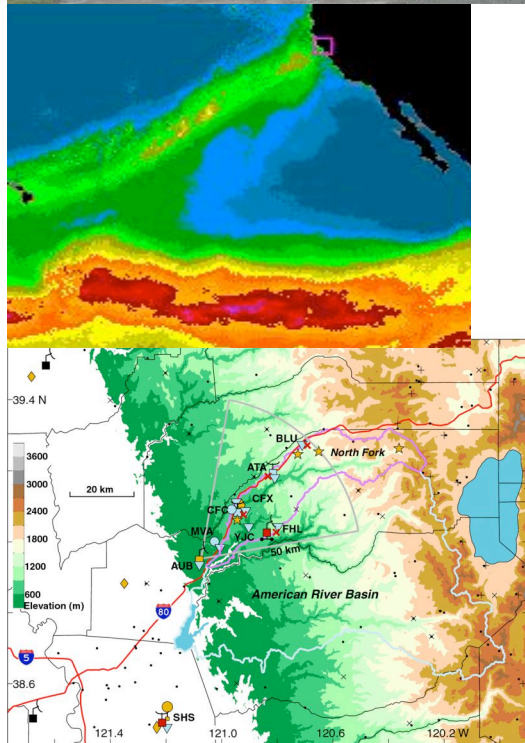
Map of Tier I-III



Map of Tier I-IV



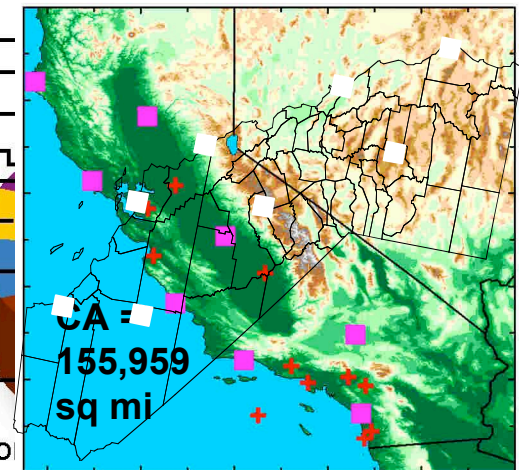
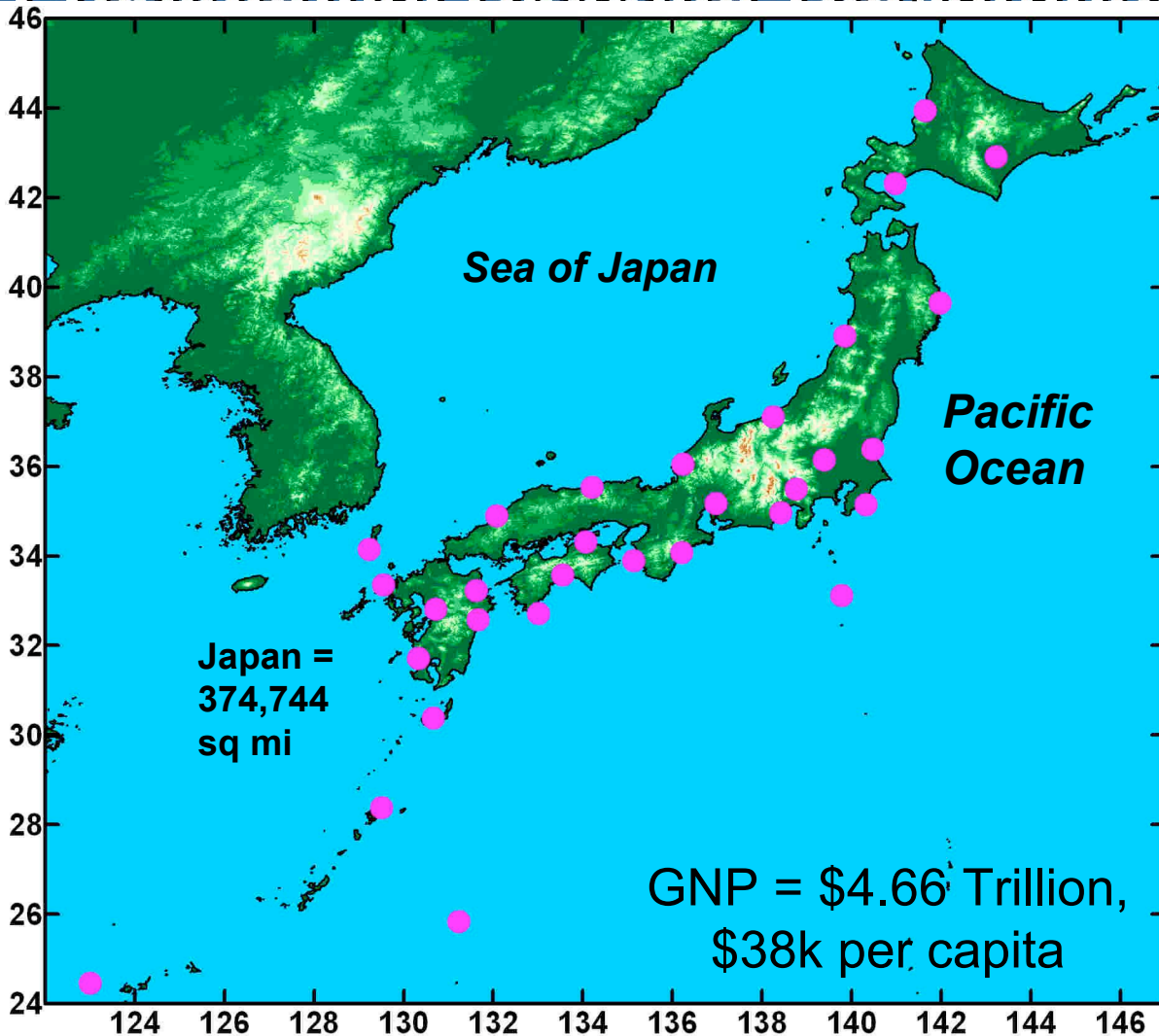
A tiered approach for new obs to help address CA's water resource issues



California faces some of the same risks from winter storms that Japan faces with typhoons

Presidential Proclamation: National Profiler Network of Japan

Tier 2: Proposed Profiler Network for CA Disasters By Type



CA GDP = \$1.62 T
\$45k per capita

*Other Hazards include: Drought, Volcano, Other, Freezing, Mud/Landslide, Typhoon, Human Cause, Terrorist, Dam/Levee Break, Toxic Substances

Source: FEMA's National Emergency Management Information System

2005 data, sources:
Wikipedia and U.S. Bureau of Economic Analysis

Conclusions

- CA Department of Water Resources is Considering implementing key elements of Tiers 1 and 2
- NOAA is examining alternatives in Tiers 3 and 4 (e.g., via the HMT and UAS Projects in FY06-10)

Conclusions

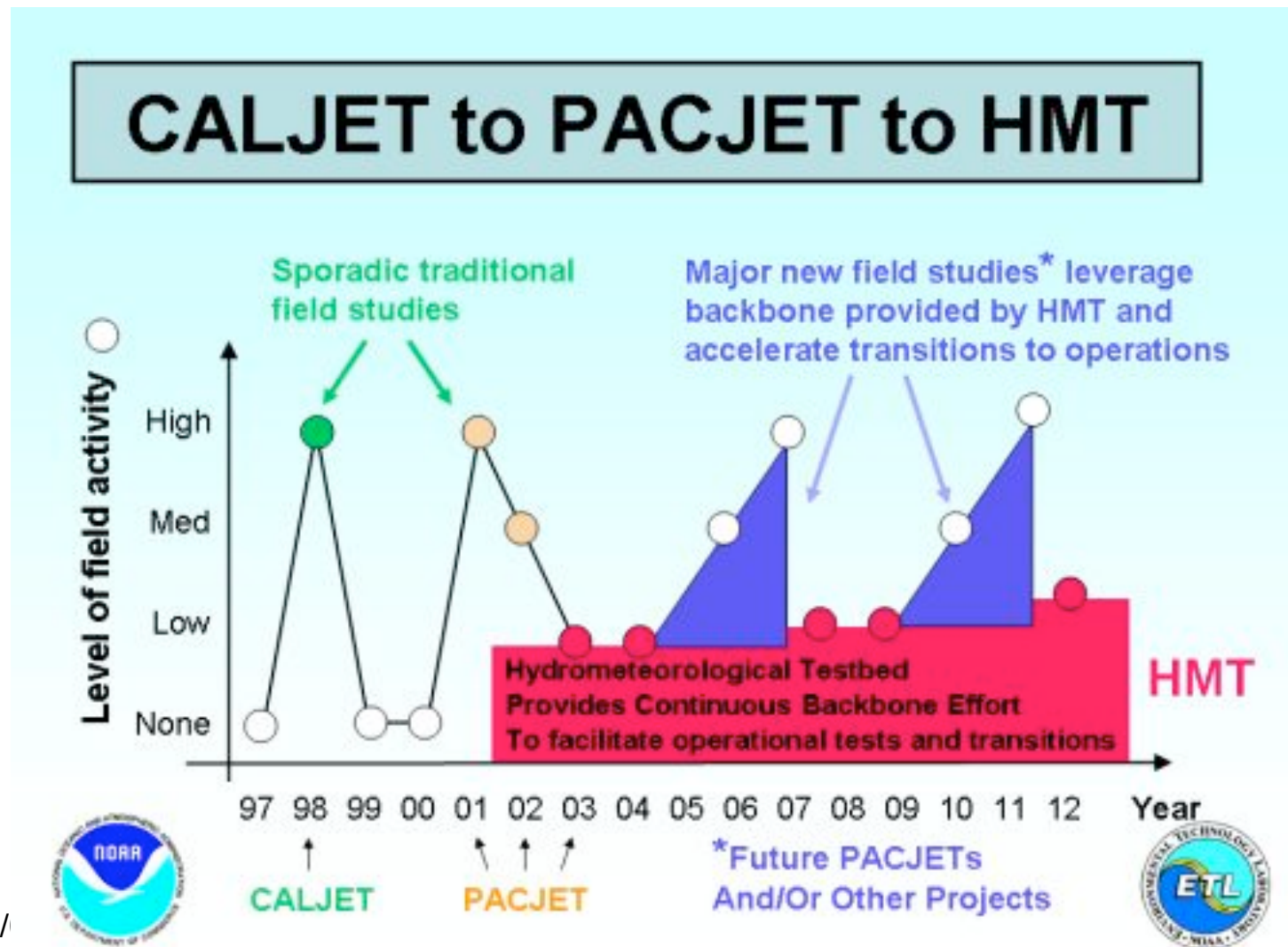
- **21st Century Water and Climate Policies and Decision Support Tools need 21st Century Observations, Models and Science**

Backup Slides

Hydrometeorological Testbed

- Background information
- See hmt.noaa.gov

10 Years of Testing and Development (1997-2007)



Hydrometeorological Testbed (HMT)

- Goal is to improve forecasts of rain and snow
- Fosters local-state-federal, and private-public-academic partnerships

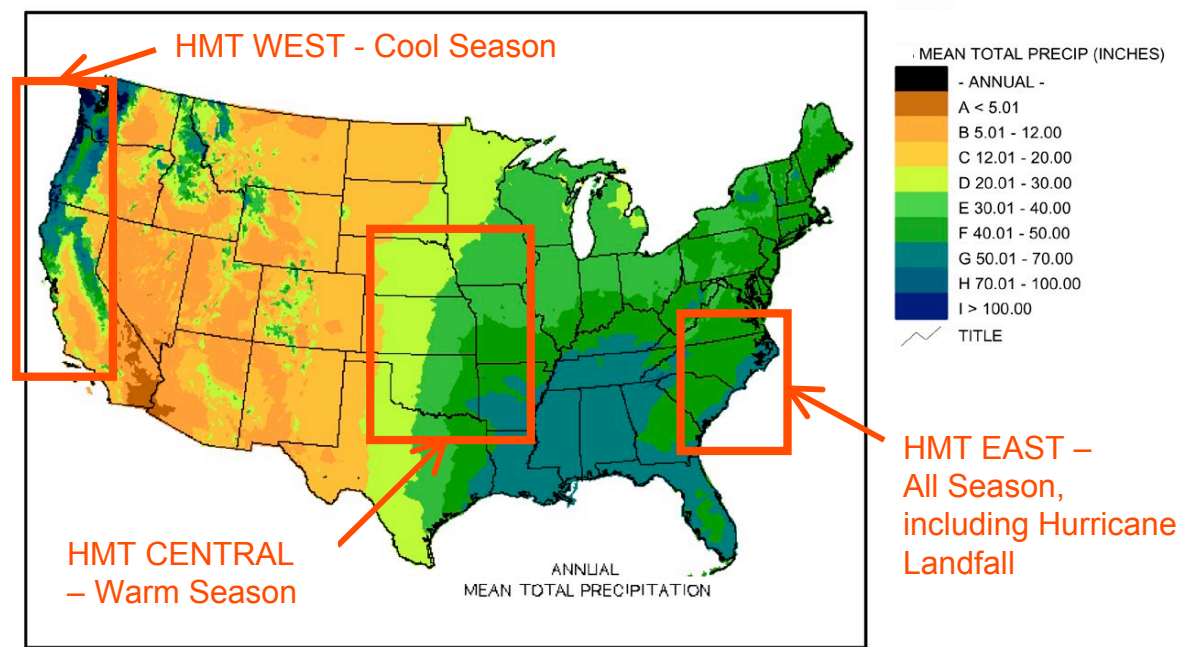
Benefits: Accelerates improvements in QPF and flood forecasting, with impacts on Transportation, emergency management, flood control and water supply. Science and field tests will advise on how best to fill gaps in observational and modeling systems.

Status:

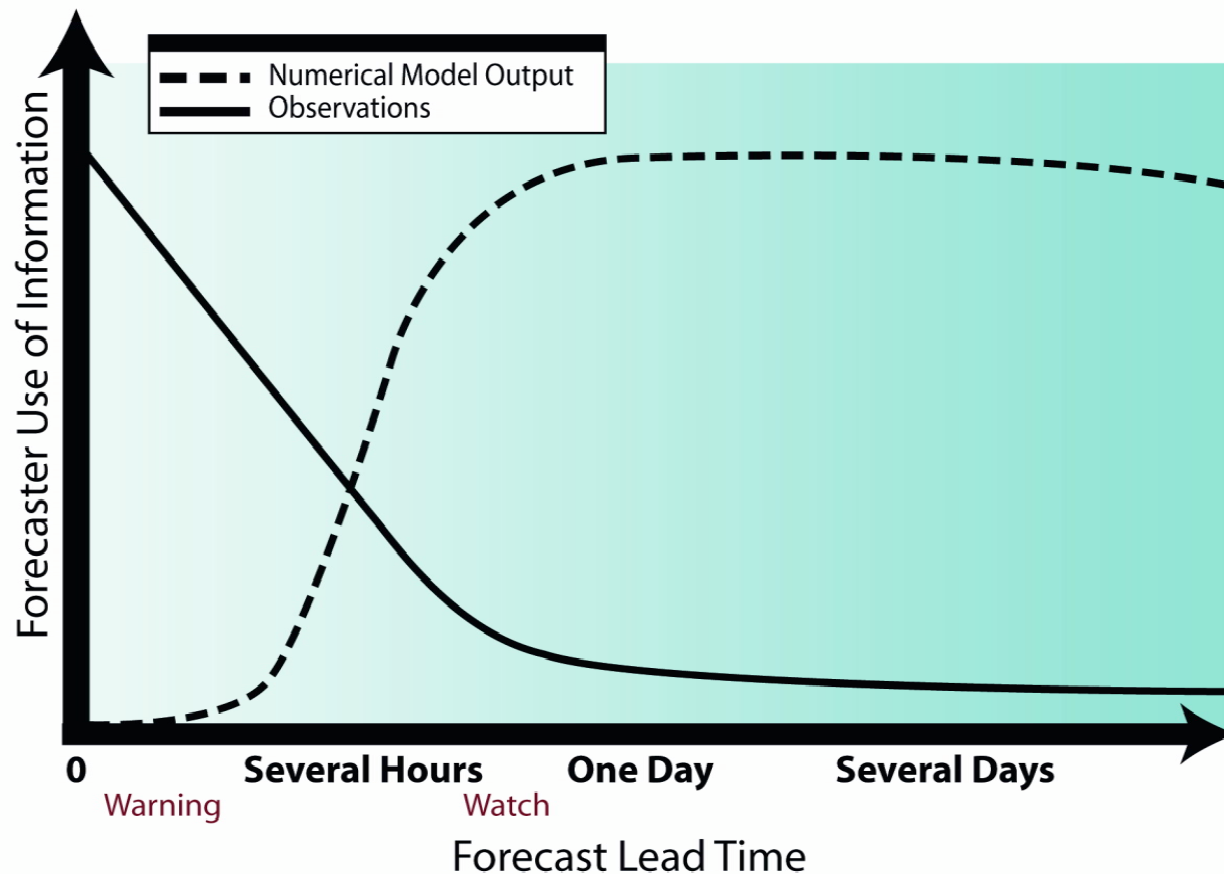
- Recommended by USWRP
- Implementing regionally
- HMT-prototype 2003-04
- HMT-West 2005-09
- Addresses Sacramento flood risk

Next Steps:

- Provide state-of-the-art QPE to evaluate hydrologic models
- Winter QPF in mountains
- HMT-East (2009-12)
- HMT-Central (2012-16)



Information Use in the Forecast Process: Results of Survey of WFOs, CNRFC, & NCEP*



Morss and Ralph, 2007, Weath. & Forecast.

Testbeds

(regional or topical)

Candidate Sensors

- surface met
- GPS receivers
- profilers
- gap-filling radars
- buoys
- etc.

Fill gaps through targeted sensor development,

e.g., buoy profilers, precipitation radars, etc.

Temporary Oversampling

Objective testing and demonstration

Final Network

Outcome

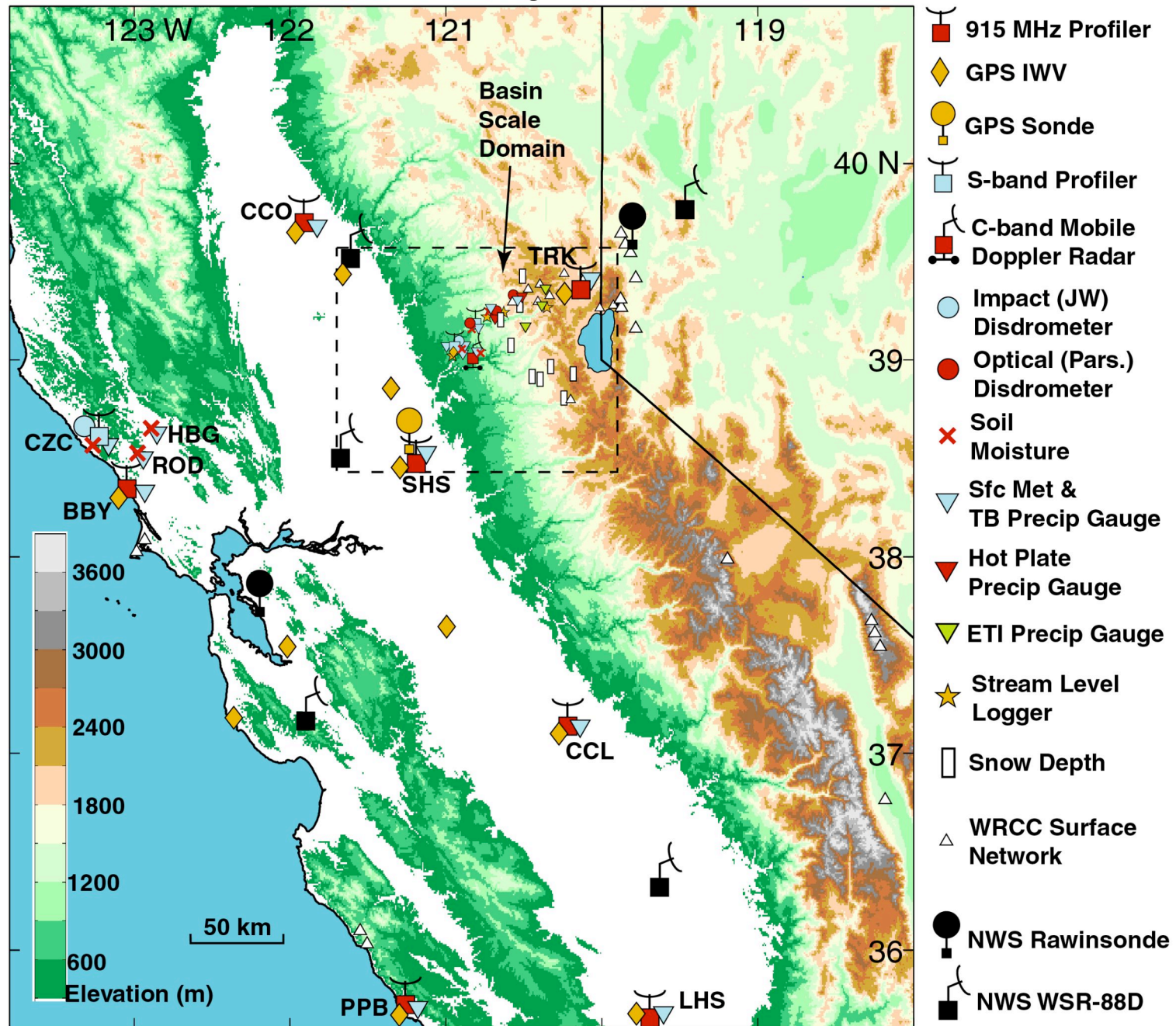
Improved services through NWP & nowcasting

Testbed results objectively inform decisions on changing the design of long-term regional observing networks

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Dabberdt et al. 2005 (Bull. Amer. Meteor. Soc.)

HMT-West 2006-2007: Regional Scale Domain

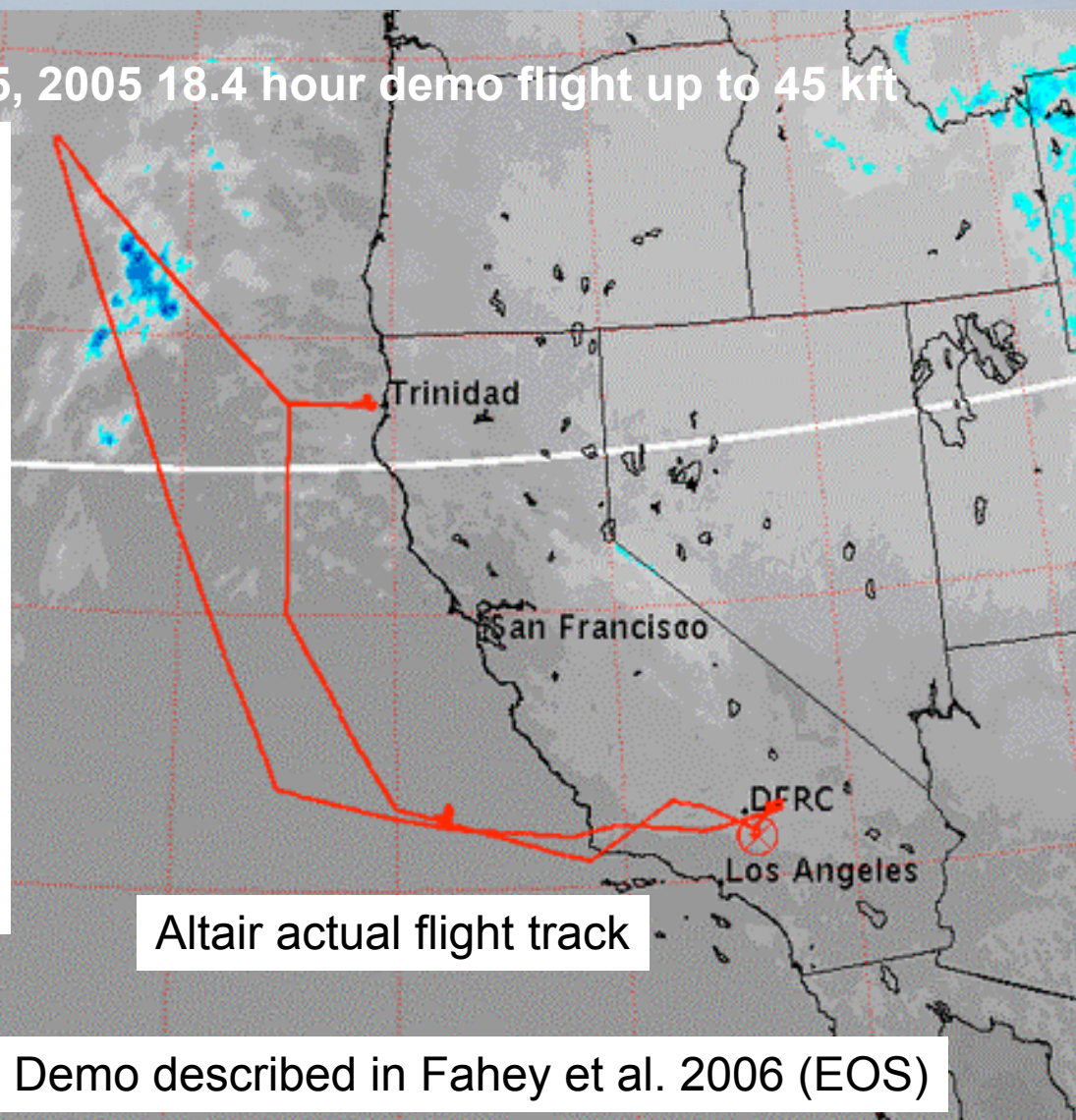


The NOAA Unmanned Aircraft System (UAS) Altair Demonstration Project

Nov 15, 2005 18.4 hour demo flight up to 45 kft

18 h flight demonstrated potential monitoring capability for atmospheric rivers

- FAA COA issued
- Technical issues overcome
- Joint effort with General Atomics
- Combined multiple missions
- Longer range possible
- Need dropsonde pod
- Mission possible from Hawaii
- Could supplement WSR

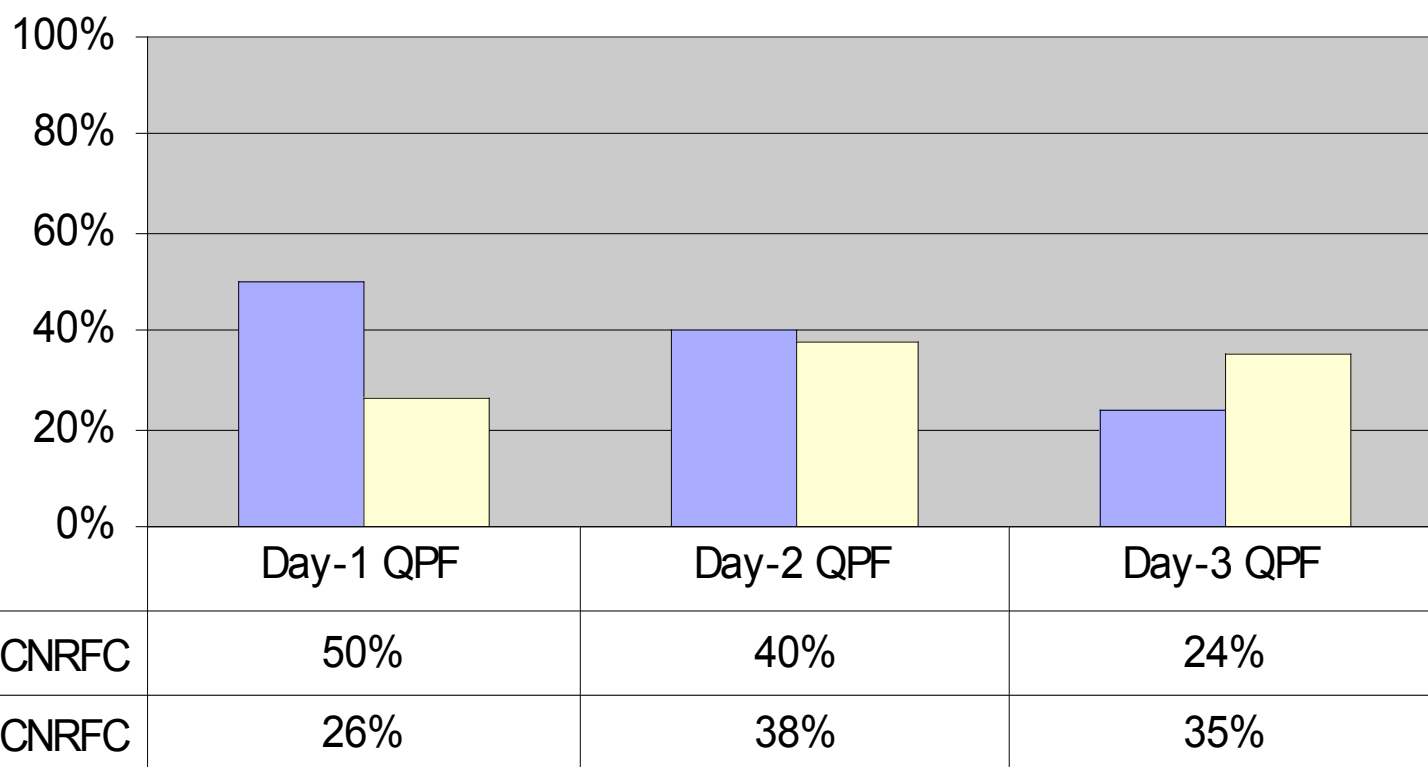


Demo described in Fahey et al. 2006 (EOS)

Extreme Rainfall is Difficult to predict

Analysis for 17 NorCal site during 2005/06 winter

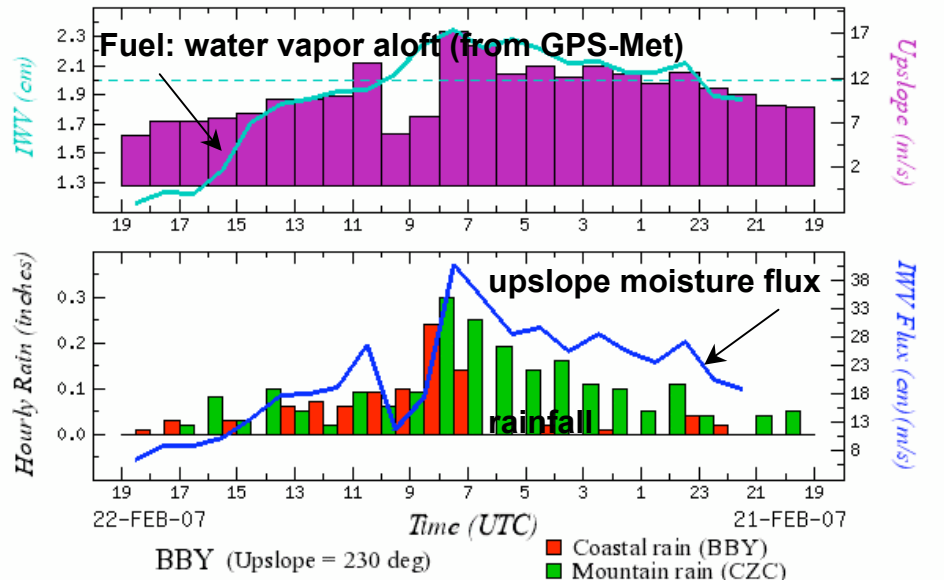
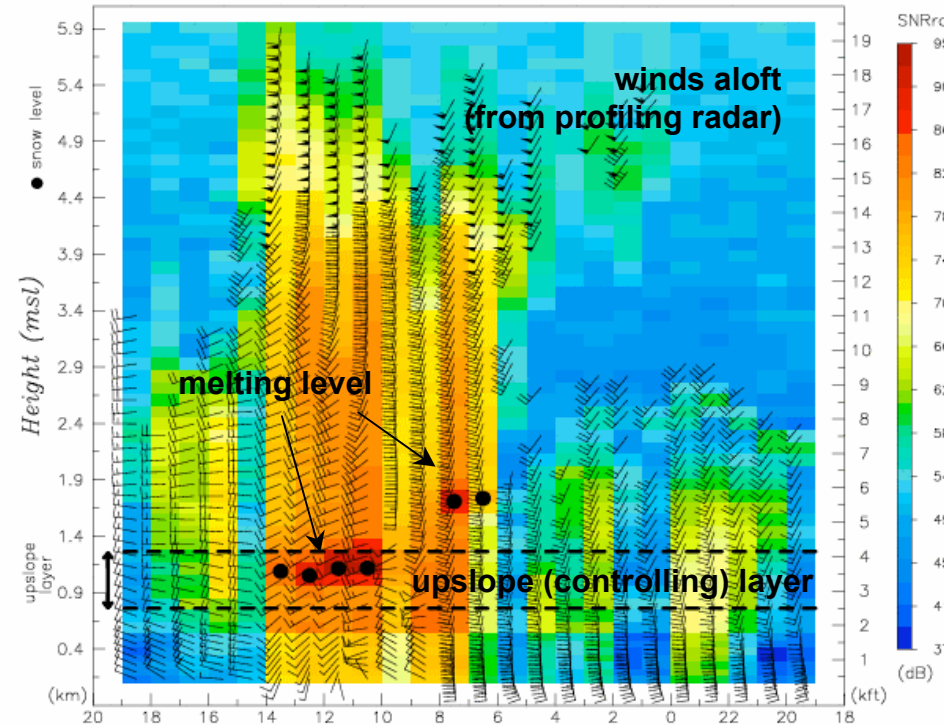
Proability of Detection (POD) and False Alarm Rate (FAR) for events with >3" rain in 24 hours (62 events)



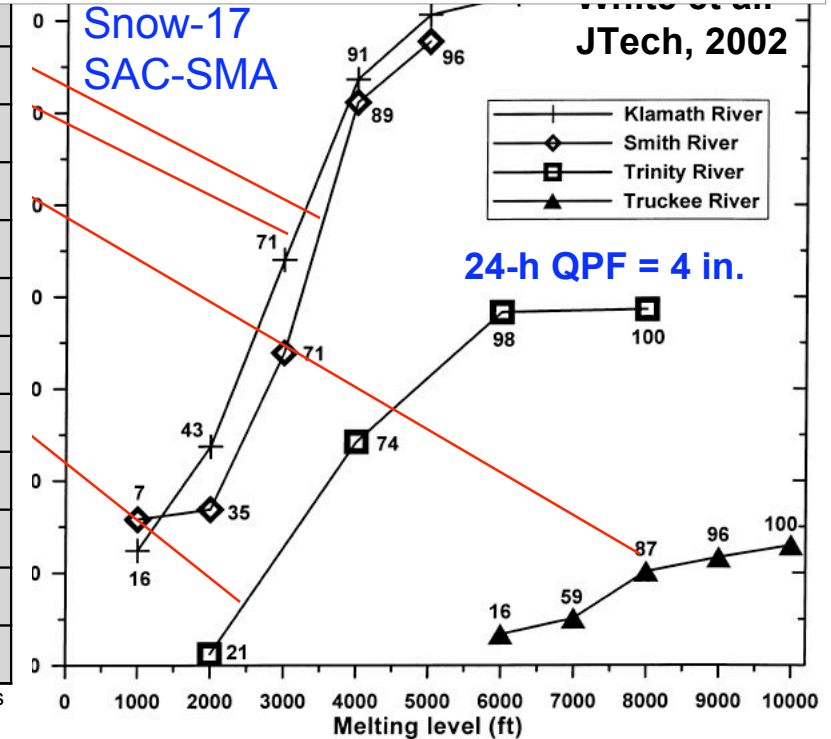
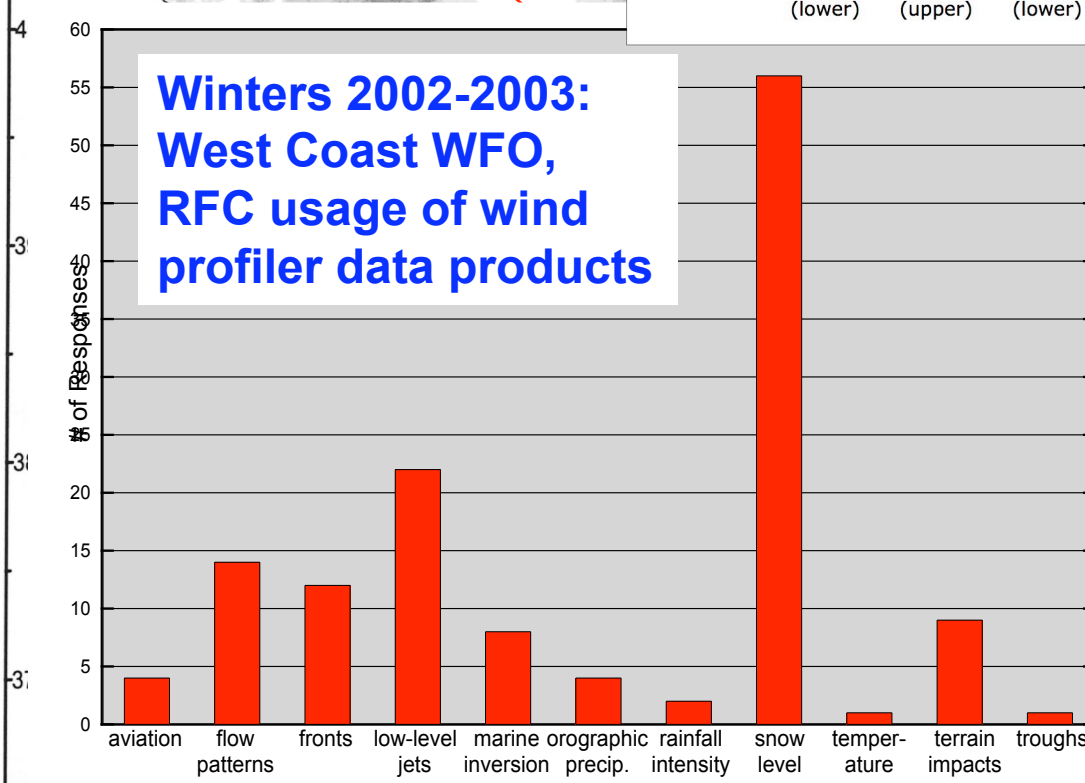
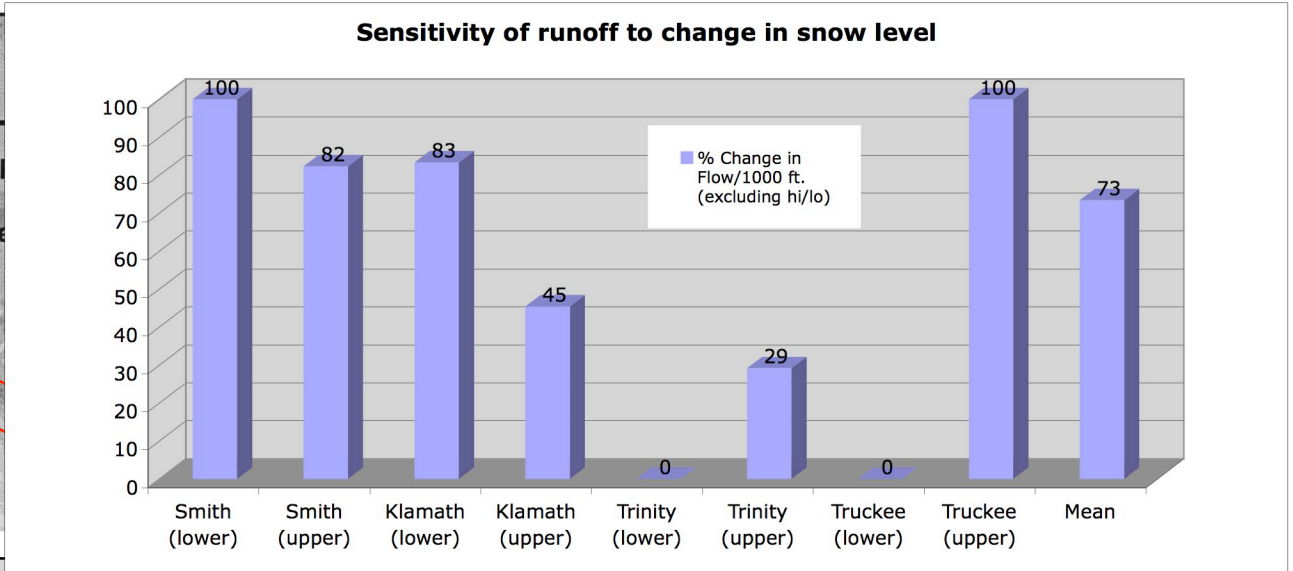
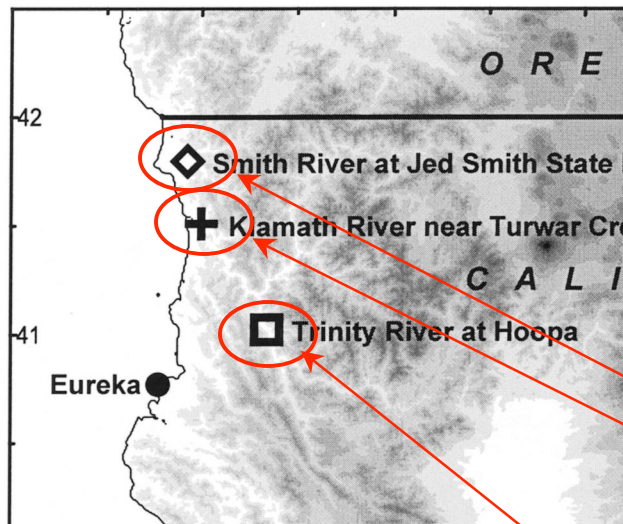
Snow Level & Moisture Flux Products



Environmental Technology Laboratory
Boundary Layer Wind Profiler Studies
Data provided by the NOAA Environmental Technology Laboratory

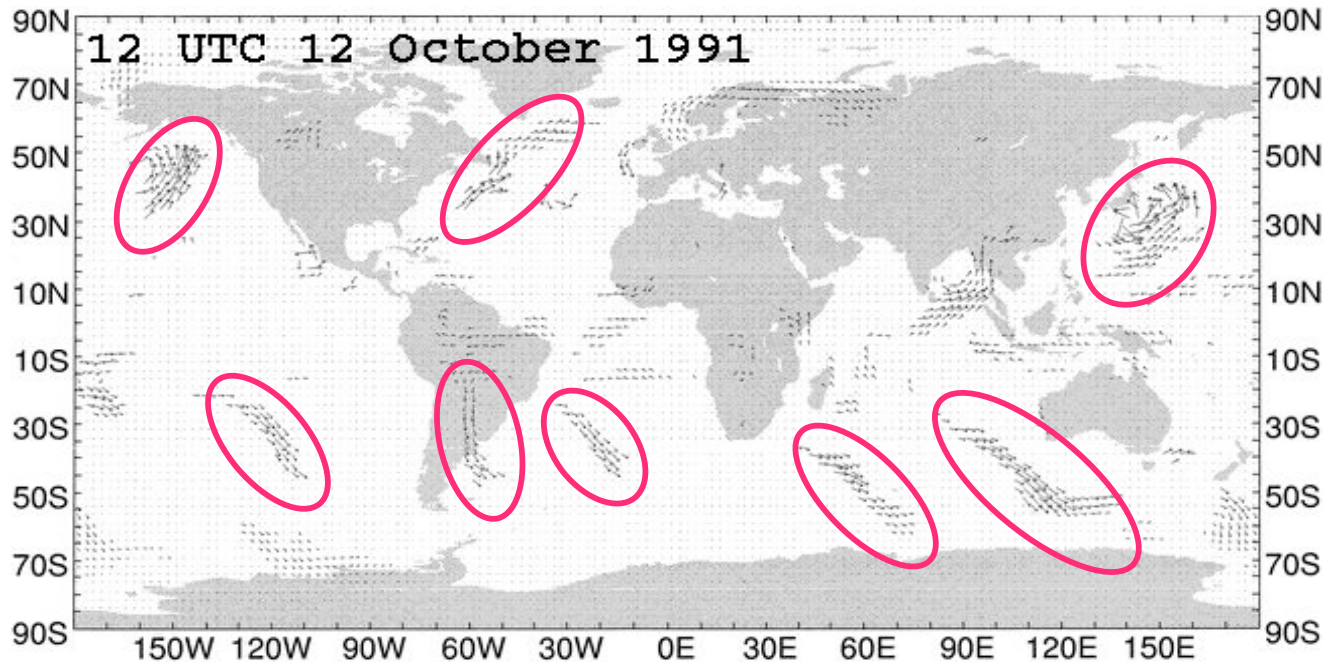


Sensitivity of Runoff to Change in Snow Level



Atmospheric Rivers

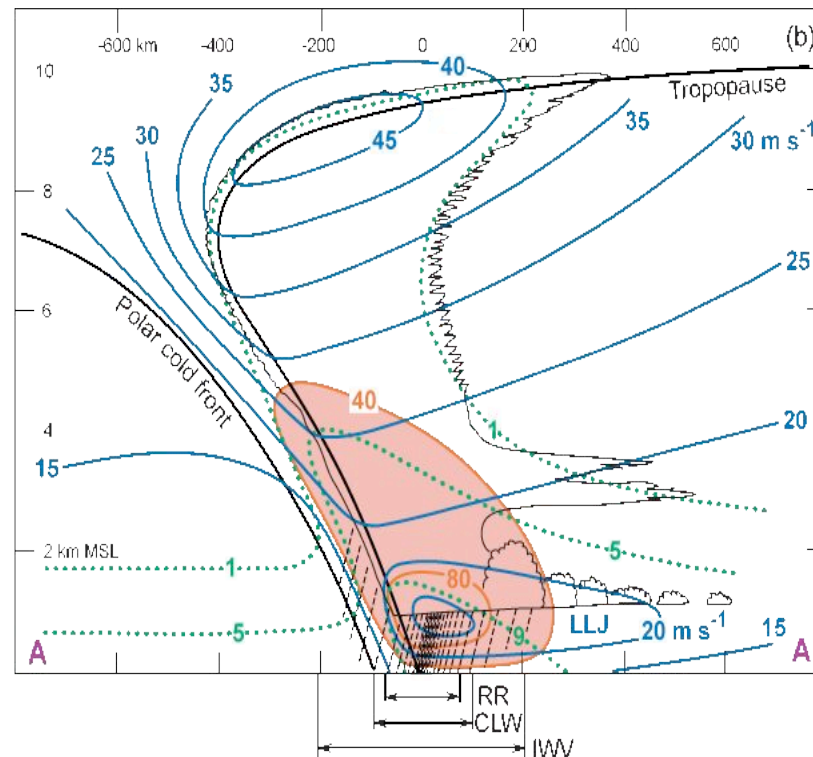
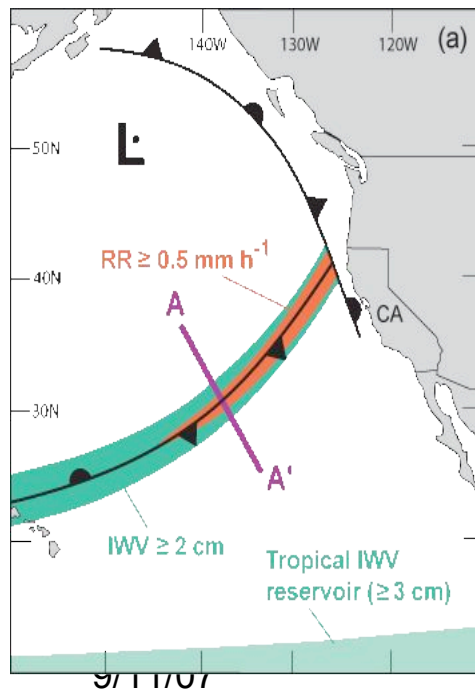
- Background information



Zhu & Newell 1998

Model diagnostic study
using the ECMWF

Atmos. rivers contain
95% of meridional
water vapor flux
at 35 latitude,
but in <10% of the
zonal circumference

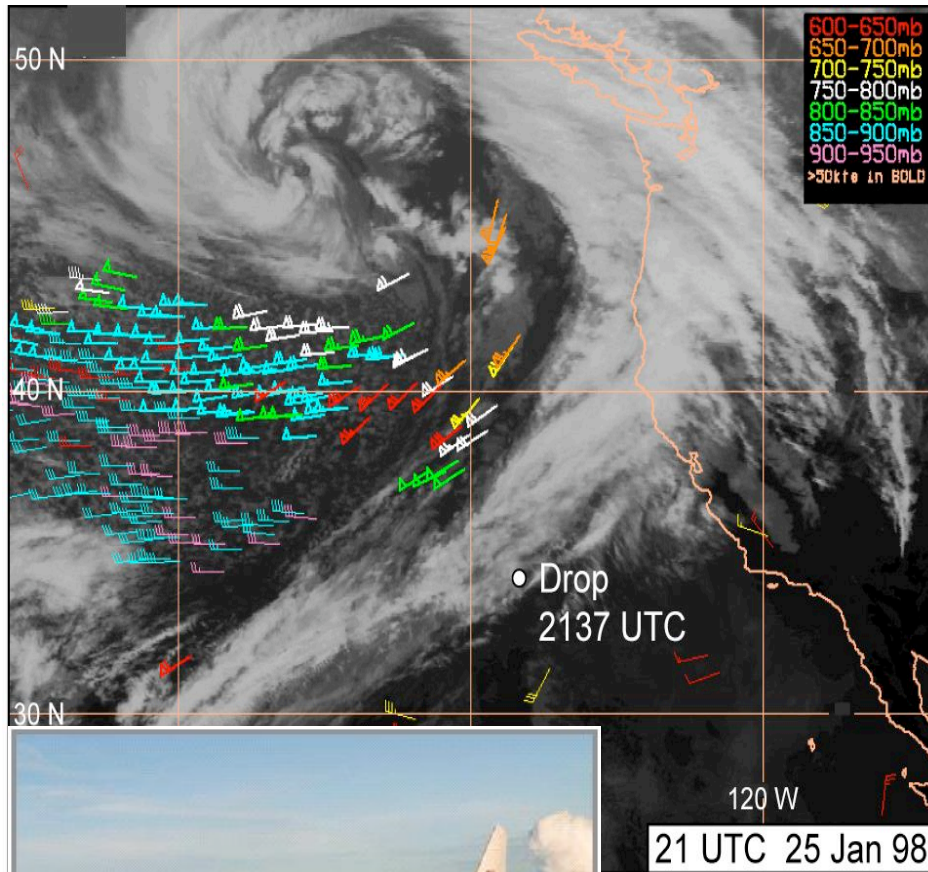


Ralph et al. 2004

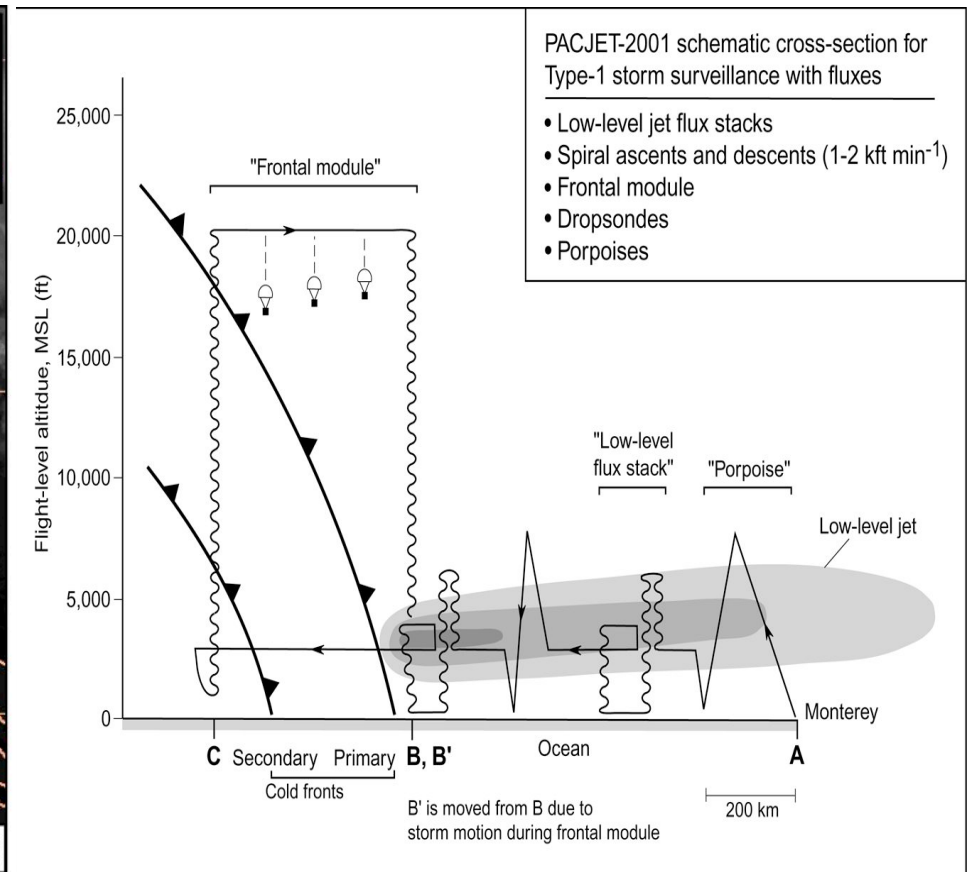
Observations confirm
model study

- Lateral structure from satellite data (~400 km width per “river”)
- vertical structure from case study
- >75% of water vapor transport is in lowest 2.5 km (Ralph et al. '05)

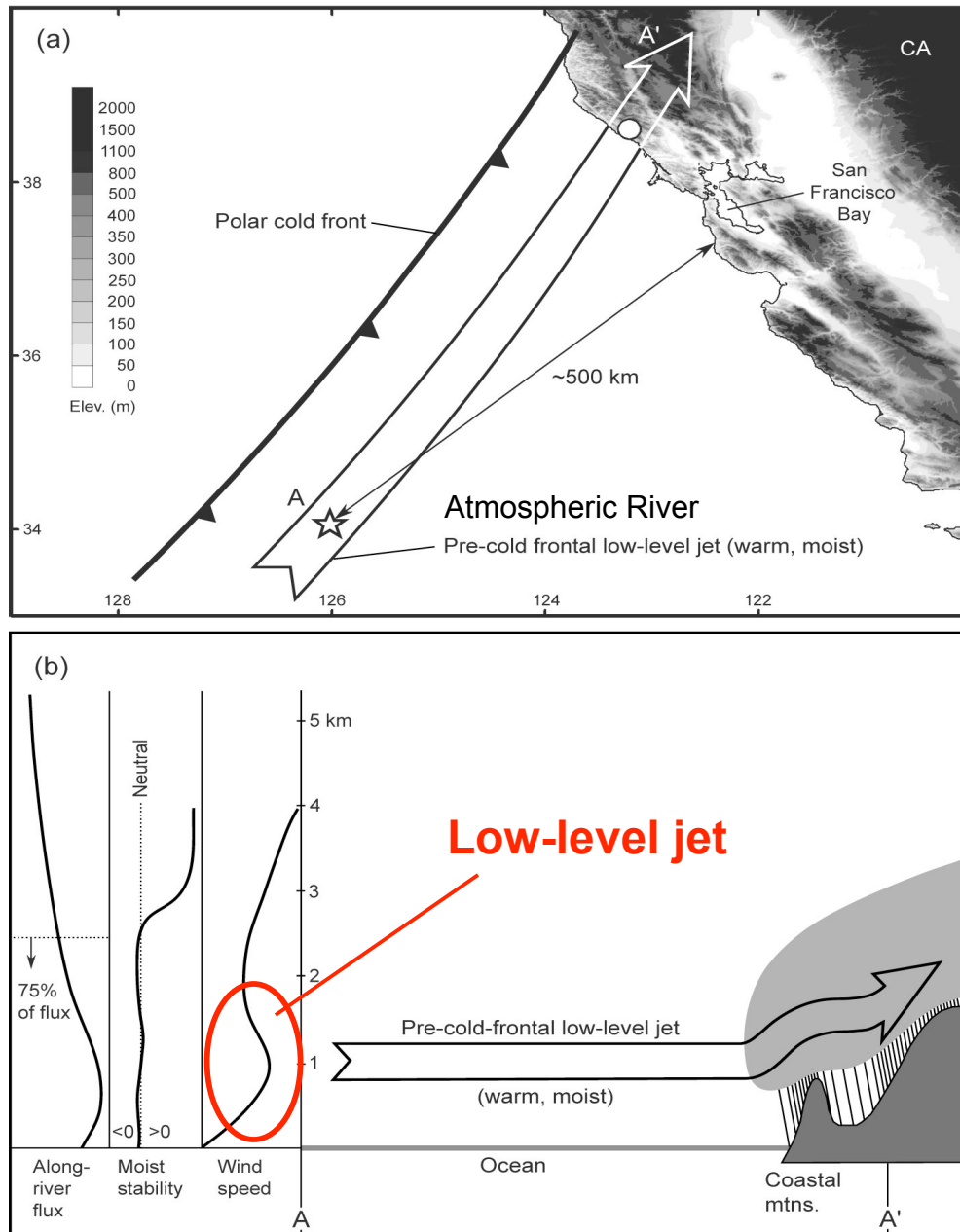
Representative storm-relative position



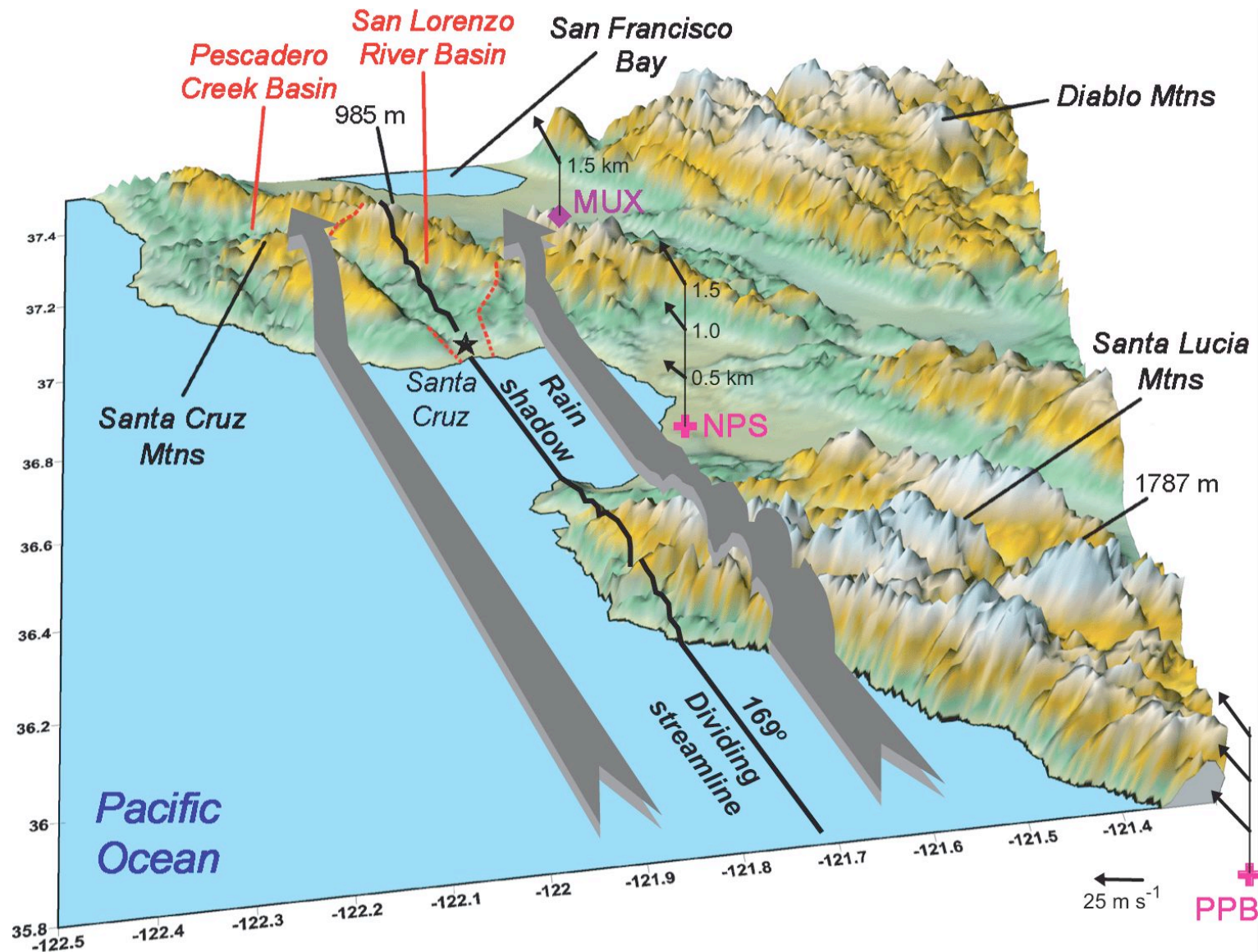
Low-level jet (LLJ) airborne observing strategy



When an Atmospheric River Strikes Coastal Mountains, it causes heavy rainfall



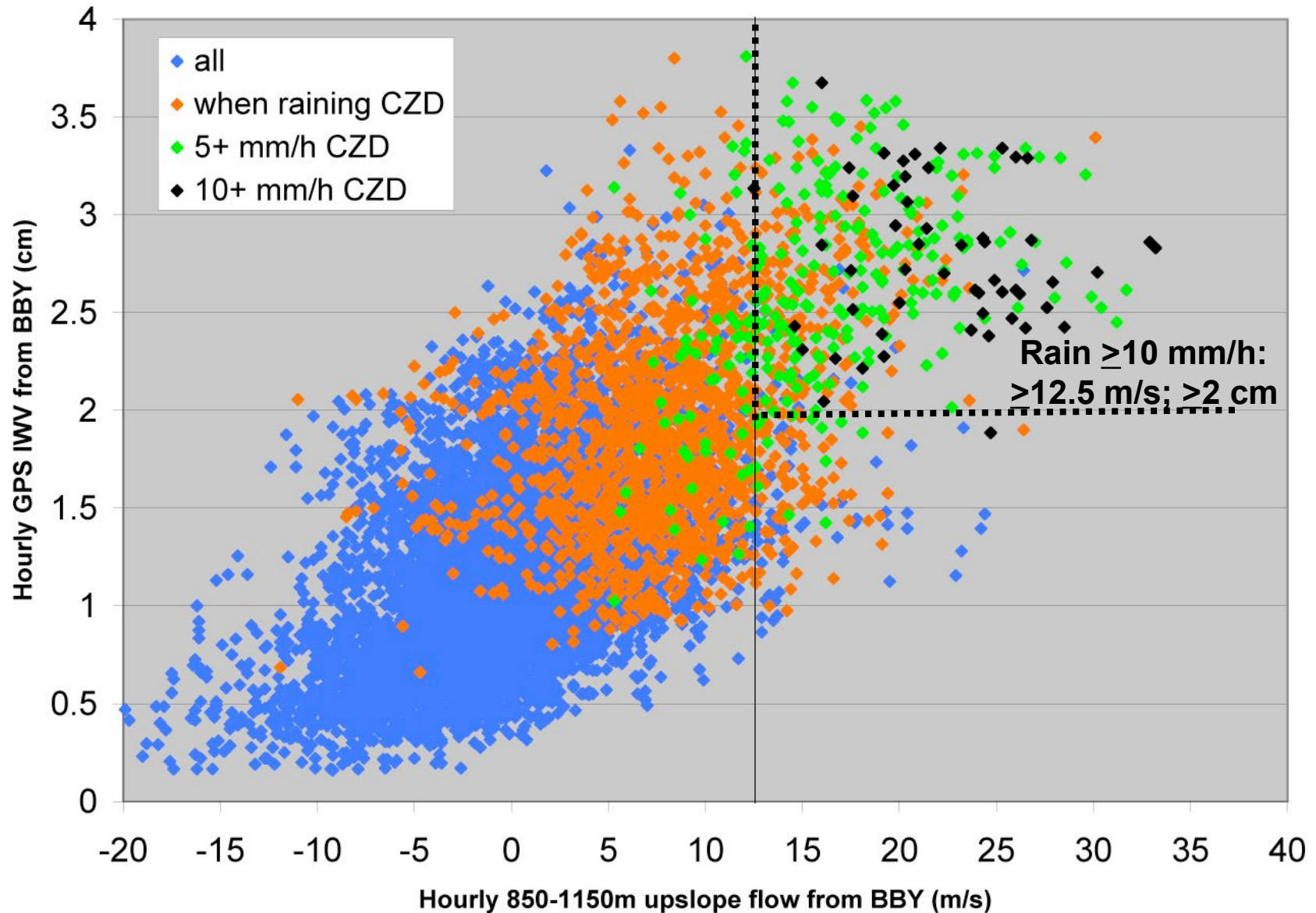
- 17 research aircraft missions offshore of CA documented atmospheric river structure.
- Wind, water vapor and static stability within atmospheric rivers are ideal for creation of heavy rainfall when they strike coastal mountains.
- These characteristics were present in both El Nino and Neutral winters



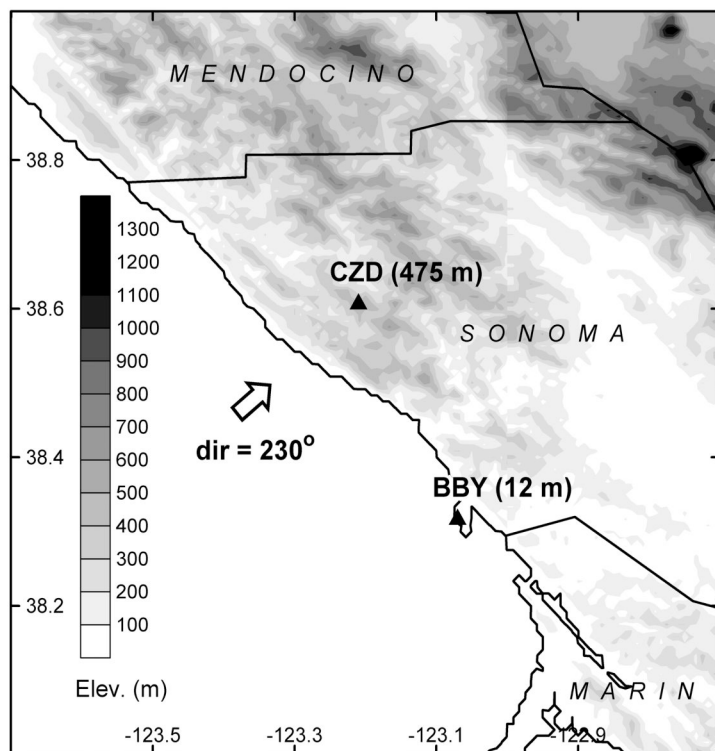
When atmospheric rivers strike coastal mountains (Ralph et al. 2003)

- Air ascends coastal mountains, water vapor condenses, heavy rainfall occurs
- Details of the atmospheric river determine which watersheds flood

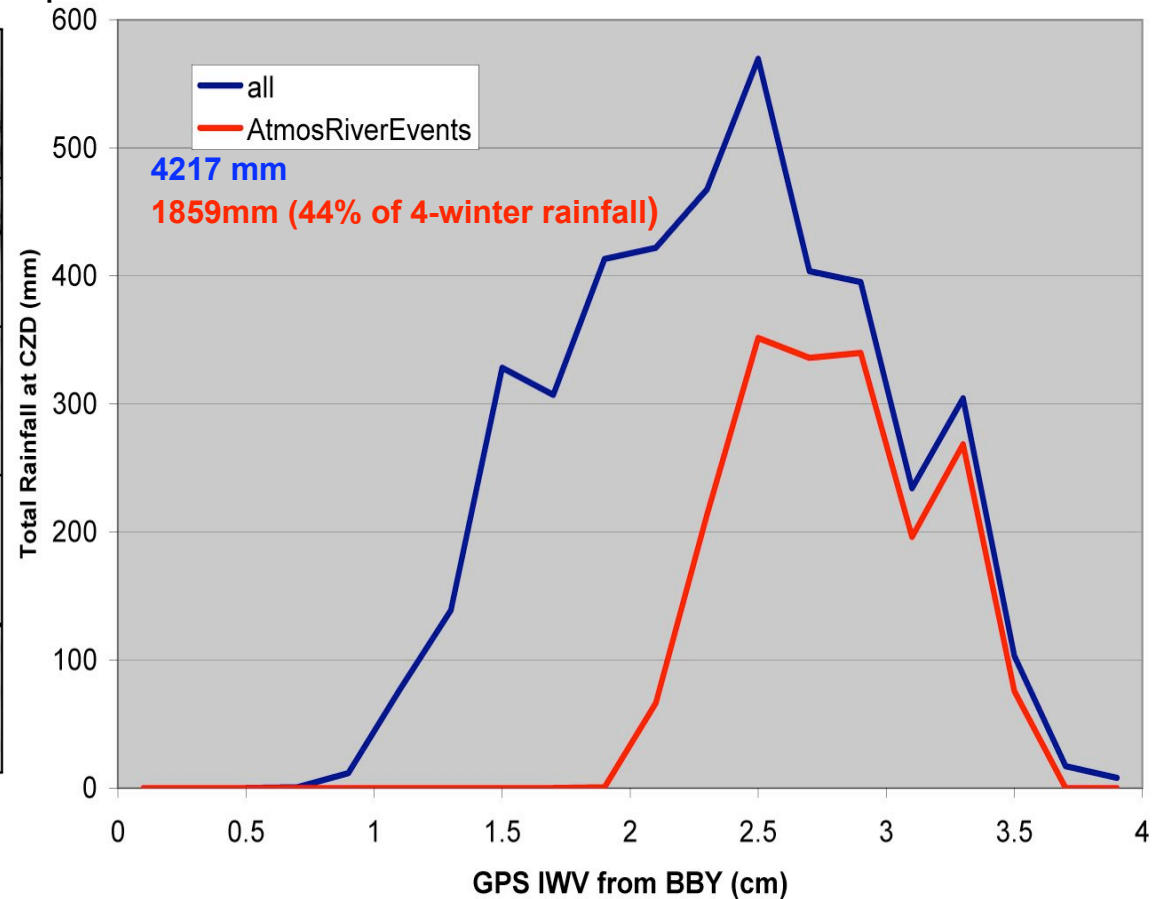
Rainfall Intensity Derived From Thresholds of Forcing (upslope wind) and Fuel (water vapor)



- Four winters of data recorded at CZD (NW of San Francisco) between 2001 – 2006.
- 9548 points of hourly data, with 1853 hours of rainfall totaling 4217 mm.
- IWV plumes ≥ 2 cm tagged by SSM/I satellites (as in Ralph et al. 2004) crossing BBY.
- GPS IWV ≥ 2 cm at BBY for at least 8 consecutive hours.
- Wind speed ≥ 13 m s⁻¹ (~25 kts) at controlling layer (850-1150 m MSL) at BBY.
- There were 31 atmospheric river events with 1859 mm of rain in 386 h.
- Atmospheric rivers produced 44% of the observed rainfall in only 21% of the time it rained.
- Bulk Rainrate: 4.82 mm h⁻¹ for atmospheric river events and 2.28 mm h⁻¹ for all rainfall.



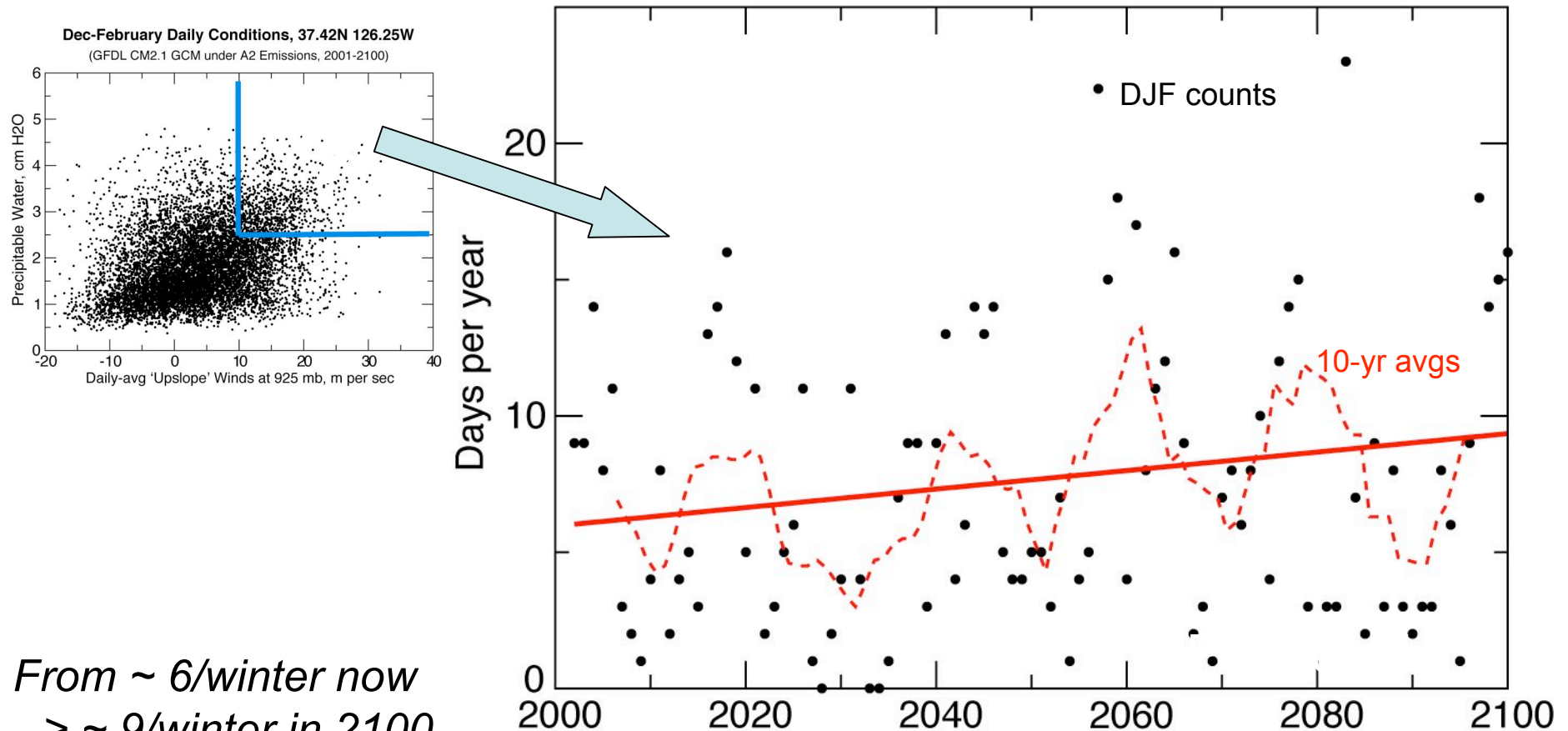
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How often are historical extreme-precip conditions realized per winter as the climate-change projection progresses?

Numbers of DJF Days in Extreme-Precip Quadrant

(GFDL CM2.1 GCM under A2 Emissions, 2002-2100)



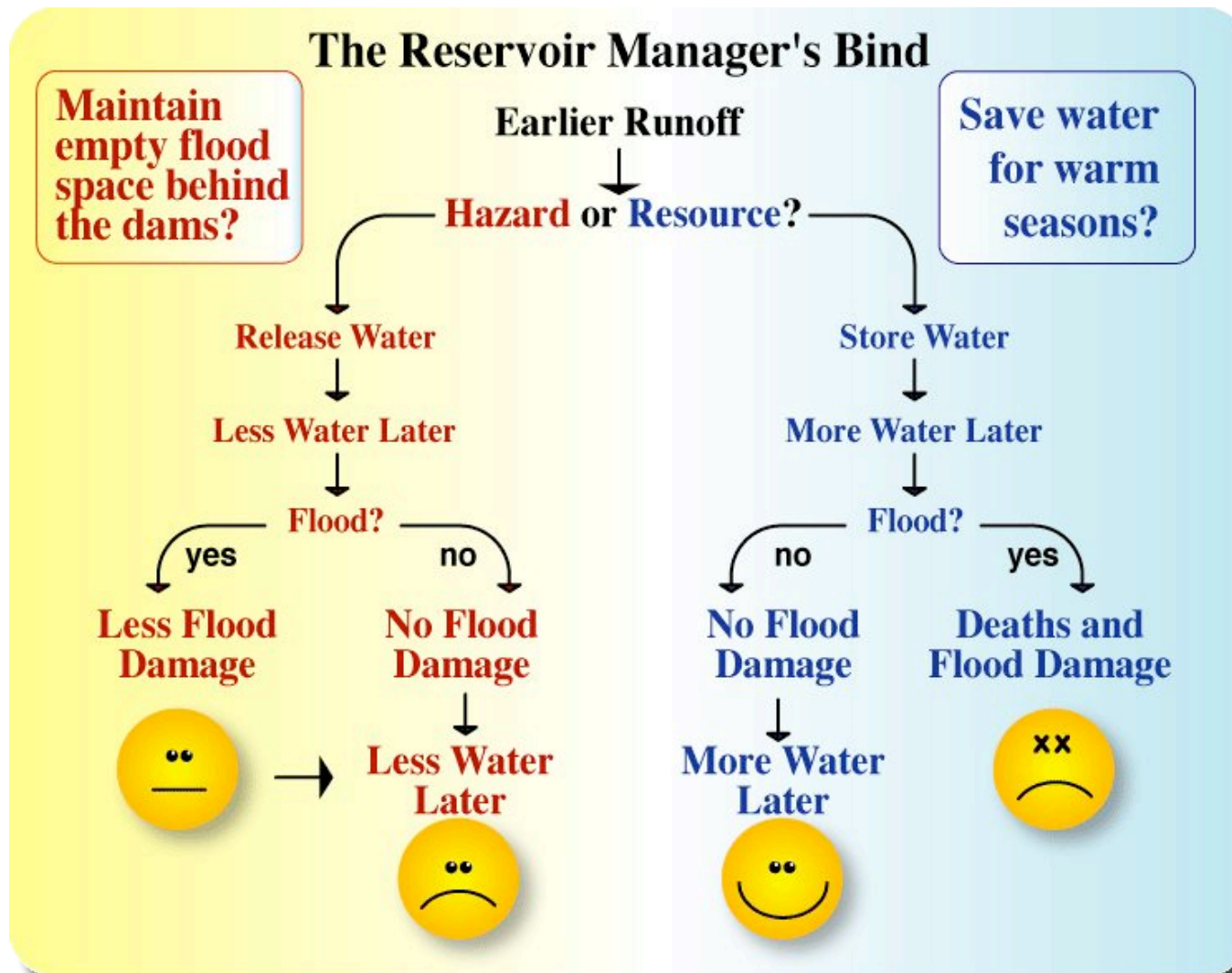
From ~ 6/winter now
--> ~ 9/winter in 2100

A 50% increase in number of "flood-worthy" storms?

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Courtesy of Mike Dettinger

Climate change may put some water managers in a real bind!



--> Storage & transferability of water supplies will thus be at a premium.

Courtesy of Mike Dettinger